P3-115 ABDALLAH, S.*; HARRACKSINGH, A.N.; MESSAK, K.; SENATORE, A.; University of Toronto Mississauga ;
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In-vitro molecular and biophysical properties of the "presynaptic" Ca_v2 calcium channel homologue from Trichoplax adhaerens, an animal that lacks synapses.

Trichoplax adhaerens is a primitive metazoan with only six cell types that lacks a nervous system and synapses. One cell type, dubbed gland cells, line the periphery of its flat disc-shaped body and resemble neurons by expressing membrane apposed secretory vesicles and proteins required for regulated neuronal exocytosis including a presynaptic Ca_v2 calcium channel homologue. Remarkably, *Trichoplax* is a motile behaving animal that can integrate sensory information with cell activity, where it will pause its ciliary locomotion upon detecting algae under its body, then locally secrete hydrolytic enzymes to lyse and consume the algae by external digestion. In this project, we are conducting a molecular characterization of the cloned *Trichoplax* Ca_v2 channel, with a focus on its biophysical and pharmacological properties, neuromodulation through G-protein coupled receptors, and interactions with presynaptic scaffolding protein RIM, all of which are crucial for Ca_v2 channel function at the synapse. Subsequently, we will explore the role of TCa_v2 in gland cell exocytosis for the purpose of coordinating cellular activity during its feeding behavior. My work will provide insights into the evolution of the nervous system, where pre-synaptic calcium channels are essential for translating electrical signals from graded and action potentials, into regulated secretion of neurotransmitters and neuropeptides.

23-4 ABEGAZ, MF*; SALAS, H; GUNDERSON, AR; TSUKIMURA, B; STILLMAN, JH; San Fransisco State Univ., California State Univ., Fresno, Univ. of California Berkley;
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Increased Density Induces Aggressive Behavior and Increased Vitellogenin Levels in Porcelain Crab Species Petrolisthes cinctipes and Petrolisthes manimaculis

Many of the consequences of global change are expected to result from changes in species interactions. Therefore, it is critical to understand the mechanisms by which thermal stress is transduced through behavioral interactions. The porcelain crab *Petrolisthes cinctipes* resides in the upper to mid intertidal zone and is expected to behaviorally respond to rising temperatures by shifting its distribution to a lower position in the intertidal zone. If they move down the shore, they will experience higher densities and likely interact more often with a congeneric competitor, *Petrolisthes manimaculis*. In this study, we addressed how increased density and inter- and intra- species interaction impacts survival and reproduction, indexed by circulating levels of the yolk protein vitellogenin (Vg). To address these questions, female crabs were randomly exposed to high density (787 crabs/m^2) or low-density (200 crabs/m^2) treatments with and without the presence of a competitor species for 14 days. We found that density and interspecific interactions both influenced survival in a species-specific manner, as *P. manimaculis* experienced significantly more mortality in high-density and interspecific treatments than *P. cinctipes*. Additionally, ELISA results show elevated Vg concentrations in *P. manimaculis* relative to *P. cinctipes* suggesting possible reabsorption of the protein in response to stressful behavioral interactions. Our results highlight the importance of species interactions under changing conditions and further our understanding of how thermal stress can impact animal populations through increased behavioral stress.

123-3 ABRAMYAN, J; University of Michigan, Dearborn;
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Heterochrony in Eye Development and its Effect on Jaw Formation

Amniotes exhibit significant heterochronic variation when it comes to eye development. Reptile embryos (including those of birds) form eyes early in development, resulting in disproportionately larger eyes when compared to mammals at similar developmental stages. In reptiles, the developing eyes span the lateral sides of the head and directly abut against the embryonic craniofacial prominences. These facial prominences will eventually fuse to form an intact upper jaw, encompassing the nasal cavities, upper lip and anterior palate. Perturbation of craniofacial fusion can result in deformation of the jaw, including the formation of clefts in the upper lip and palate. Due to the position and substantial size of the embryonic eyes in reptiles, we hypothesized a role for them in influencing craniofacial fusion by pushing the prominences forward during development. However, this hypothesis is at odds with the fact that mammals exhibit a delay in eye development and yet manage to undergo fusion seamlessly. In this study, we performed unilateral ablation of the eye primordium in chicken embryos and allowed them to develop past the point of craniofacial fusion. Contrary to expectation, reduction in eye size does not seem to have an effect on the fusion of the upper jaw in the chicken embryos. Fusion was observed simultaneously on both ablated and untreated sides of the face, despite minor changes in size, shape and position of prominences. This demonstration of independence between the facial prominences and the developing eye explains how the amniote eye may undergo allometric heterochrony without significantly affecting fusion of the upper jaw. However, later embryonic stages did exhibit significant deviation of the ossified upper beak towards the ablated side, indicating reliance of the overall morphological integrity of the skull on the developing eye.

24-1 ACKERLY, KL*; MITROFANOV, I; SANFORD, CP; KRAHE, R; CHAPMAN, LJ; McGill University, Kennesaw State University, Humboldt-Universität zu Berlin;
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Mismatch Between Morphology and Performance Among Elephant-nose Weakly Electric Fishes From Divergent Habitats

Body morphology influences swim performance in fishes and is often reflective of natural habitat. In general, fish living in high-flow habitats (e.g., river rapids) tend to have more streamlined bodies and fins designed for steady swimming, while fish from low-flow, structurally complex habitats (e.g., swamps) tend to be maneuverable with large fins that aid in unsteady swimming. Here, we quantified the relationship between morphology and swimming performance across closely related species of wild-caught elephant-nose mormyrid fishes from divergent habitats. A suite of techniques, including geometric morphometrics, were used to characterize differences in body and fin shapes among *Campylomormyrus* spp. from a high-flow habitat, an open-water species (*Gnathonemus petersii*), and a swamp-dwelling population of *Marcusenius victoriae*. We also determined swimming capabilities of each species at four swim speeds (0.5-2.0 body lengths s^{-1}). While our results confirmed morphological differences among species reflect their natural habitats (e.g., high-flow fish are more streamlined than swamp fish), we found a mismatch between morphology and performance. The high-flow *Campylomormyrus* spp. spent significantly more time swimming unsteadily at every speed compared to *G. petersii* and *M. victoriae*. This can be explained, at least in part, by differences in head shape among species, which may influence swimming patterns more than overall body shape. Our results highlight the importance of considering head morphology when studying swimming performance. We suggest future studies in these fishes investigate performance in turbulent flows, as they may be more reflective of the flow regimes they encounter in their natural habitat.

26-2 ACKLES, AL*; STORCH, JD; HERNANDEZ, LP; George Washington University; *alackles@gwu.edu*

An Exploration of Morphospace Occupation of the Cypriniform Pharyngeal Jaw

The order Cypriniformes consists of over 3,000 species and makes up over one-tenth of all living bony fishes. Multiple novel feeding innovations -- including the loss of oral teeth, the loss of the upper pharyngeal jaw, and the loss of the stomach -- shift the load of food processing entirely onto the pharyngeal teeth and lower pharyngeal jaw (LPJ) within this group. Since the LPJ plays such a singular role in food processing, quantifying the diversity of the cypriniform LPJ may help us understand how this group has diversified and adapted to novel feeding environments. Here we investigate cypriniform LPJ morphospace occupation in order to determine whether diversity in shape of the LPJ is more closely correlated with function or phylogeny. We build and analyze a geometric morphometric morphospace of over 60 genera containing altogether more than 90 species of Cypriniformes. Each specimen is characterized by 5 landmarks and 36 semilandmarks along the tooth-bearing face of the LPJ. Generalized Procrustes analysis superimposes these coordinates to a common space that isolates variance in shape. Projection from this space via principal components analysis allows us to describe major axes of shape variation. Using our own shape data in combination with trophic information and phylogenetic analyses found in the literature, we are able to quantify and interpret patterns of diversity within the cypriniform pharyngeal jaw.

84-1 ADAMS, CIM*; HOEKSTRA, LA; MUELL, MR; JANZEN, FJ; University of Otago, Dunedin, NZ, Iowa State University, Ames, Iowa; *turdlez@gmail.com*

Estimating aquatic reptile density under field conditions using environmental DNA in Iowa, United States of America.

Density monitoring is imperative to understand population fluctuations. One emerging ecological tool for monitoring species is environmental DNA (eDNA), the technique of obtaining target DNA from environmental samples such as water, soil, or air. We evaluated if eDNA can be used for monitoring aquatic reptile density in a semi-natural lentic pond environment. Using four outdoor experimental ponds with varying Painted Turtle (*Chrysemys picta*) densities, we quantified both total eDNA and species-specific eDNA for comparison across ponds between 1 April and 30 June 2016. We found significant differences in total eDNA among ponds and a non-linear effect of time on total eDNA accumulation. We were largely unable to amplify turtle eDNA from the water samples despite developing a sensitive species-specific assay, highlighting the limitations of detecting this aquatic reptile under field conditions. Nonetheless, turtle eDNA increased in an expected rank-order pattern with increasing turtle density. Thus, eDNA retains potential to effectively measure density of aquatic reptiles in lentic systems.

118-6 ADAMS, DA*; FISH, FE; ZUE, R; BART-SMITH, H; West Chester University, Pennsylvania, University of Virginia, University of Virginia ; *da762671@wcupa.edu*

Properties and functions of tendons in the cetacean peduncle

The flukes of cetaceans are the principal structure used to power swimming. Dorso-ventral oscillations of the caudal flukes generate lift-based thrust that allows cetaceans to operate with a high propulsive efficiency. This high efficiency has been assumed to partially result from the release of elastic energy stored during the oscillatory cycle from various body components. There are three sets of tendons that pass through the cetacean peduncle and insert onto the posterior caudal vertebrae that may be associated with energy storage. The purpose of this study was to investigate cetacean tendon anatomy and elasticity through dissection, histology, and mechanical tensile testing of the tendons. Tensile testing was performed on the excised tendons with an Instron 5848 MicroTester. Histological analysis of collagen fibers was performed on the tendons. Dissections conducted on various dolphin species revealed two sets of tendons on the dorsal side (epaxial I and II) and one set on the ventral side (hypaxial) of the tail base. The epaxial I and hypaxial tendons inserted serially along the posterior caudal vertebrae. Epaxial II tendons were smaller in diameter and inserted only on the terminal caudal vertebrae. The collagen fibers that make up the three sets of tendons in the cetacean peduncle were found to be longitudinally wavy, suggesting elastic properties. The excised tendons of bottlenose dolphins (*Tursiops truncatus*) and harbor porpoises (*Phocoena phocoena*) were shown to act similar to a spring to store elastic energy. The tendons of dolphins in the caudal peduncle were revealed to exhibit spring-like properties that can potentially affect the energetics of swimming.

102-4 ADDIS, EA*; PRICE, K; KITTRIDGE, C; DAMBY, Z; Gonzaga University; *addis@gonzaga.edu*

Country Life May Not Be Stress-Free: Fecal Glucocorticoids in Yellow-Bellied Marmots along a Rural-Urban Continuum

With increasing urban development, animals are being challenged by new environments to acclimate, adapt, or move in order to survive. Ecological examinations have been extensive on animal patterns associated with urbanization, but physiological studies are rarer, particularly in mammals. This study attempts to increase our understanding of how a mammal physiologically interprets its environment by measuring a proxy of allostatic load, glucocorticoids. We examined levels of fecal glucocorticoid metabolites (FGMs) in a species that lives in both rural and urban environments, the yellow-bellied marmot (*Marmota flaviventris*), along a rural-urban continuum. We hypothesized that if marmot's allostatic load is higher in urban environments, their FGMs will be higher. However, if their allostatic load is higher in rural environments, we predicted FGMs would be higher in rural populations of marmots that urban ones. After constructing a rural-urban continuum, we found that FGMs levels were higher in adult marmots living in more rural sites and that there was no effect of the environment on FGM levels in young marmots. We discuss these results and possible future studies here.

P3-208 ADINEH, S; ROSS, J*; California State University, Fresno; *jross@csufresno.edu*

Fitness Benefits of Paternal Mitochondrial Transmission in Intra-Species Hybrids

Although mitochondria are predominantly inherited maternally, empirical results suggest that hybridization often elicits paternal mitochondrial transmission. Thus, it is possible that hybridization, through separation of co-evolved mito-nuclear epistatic loci, causes dysfunction of processes involved in paternal mitochondrial elimination. Evidence from the nematode *Caenorhabditis briggsae*, a relative of *C. elegans*, suggests that paternal mitochondrial transmission occurs during the production of intra-species cytoplasmic-nuclear hybrids (cybrids). These hybrids, in which the mitochondrial genome of one population is combined with the nuclear genome of another, sustain paternal "leakage" at fertilization, and thereafter cybrids often fix the paternal mitotype. This pattern raises the possibility that fitness is compromised when co-evolved mitochondrial and nuclear alleles are separated during hybridization, and that paternal mitotypes that do enter the oocyte at fertilization might improve individual fitness. Subsequent selection for individuals with increasing levels of the paternal mitotype might eventually lead to homoplasmy for the paternal mitotype in the presence of the paternal nuclear background. While our data suggest that this process occurs over only several generations, future efforts will focus on better understanding the tempo of paternal mitochondrial transmission and the identification of loci involved in facilitating hybrid paternal mitochondrial transmission. This information will be useful in understanding the evolution of uniparental mitochondrial transmission.

46-4 ADJERID, K*; SOOD, N; DE VITA, R; SOCHA, J; Virginia Tech, Pulaski County High School; *adjerid@vt.edu*

Variation in Young's modulus of tracheal tubes in the beetle (Zophobas morio)

Insects breathe using a complex network of rhythmically collapsing tracheal tubes, facilitating active ventilation. In some insects, including Zophobas morio, the tracheae collapse in an uneven pock-mark like pattern, but not all collapse patterns are identical, nor do tracheae collapse at the same hemolymph pressures. The softer semi-chitinous walls of tracheae are reinforced with rings of taenidia, made primarily of stiffer sclerotized chitin fiber bundles, possibly providing a materials-based explanation for varying compression patterns. Teanedia also vary in branching, width, and orientation. Here we ask, do the tracheae vary in Young's modulus along their lengths? We also compare these changes between the individual components of the tubes. We hypothesize that the teanedia will have higher Young's modulus and variance than the intertaenidial portions of the trachea, contributing to significant variability in tracheal stiffness. To quantify variation in Young's modulus, we used atomic force microscopy (AFM) to measure local Young's moduli at regular intervals along the length of the tubes. Sections of tracheae were excised from the left dorsal meso-thoracic tracheal trunks in 7 darkling beetles. We found that the Young's modulus measurements clustered bimodally between lower (0.44±0.04 GPa) and higher values (4.92±3.41 GPa) in the data sets analyzed (n = 4). The lower values, which may be the softer basal layer of the tracheae, are relatively constant while the higher values, which may be the stiffer teanedia, vary much more (1.73-10.67 GPa). As a composite material, varying the stiffness of the reinforcing teanedial fibers can change the effective stiffness of the tracheae more efficiently than changing all the individual components' stiffness independently to achieve the same variation. Supported by NSF 1558052 and 1301037

13-4 ADREANI, MN*; TER MAAT, A; GAHR, M; Max Planck Institute for Ornithology; *mnadreani@orn.mpg.de*

Breeding Changes Hearing? Context-driven Auditory Plasticity in Zebra Finches

How individuals vocally interact between, and perceive, each other within a couple are central traits of many vertebrates including humans. In different contexts, tuning between vocal communication and acoustic perception can have a critical role in the success of the couple. Songbirds provide great study models as they communicate using diverse vocalizations, from learned songs to soft calls, and possess defined brain regions specialized in the production and perception of such vocalizations. Likewise, the life stage can affect the vocal communication within couples and although extensive research suggests seasonal or reproductive-dependent changes in neural auditory responses, no study has demonstrated this to date. We report experiments designed to determine whether communication dynamics and neural responses of the auditory area nidocaudal mesopalium (NCM) adjust to the life stage, and if so, if this occurs equally in both sexes. Using wireless electrophysiology and audio transmitters in freely behaving zebra finches we found that females change their auditory responses towards socially relevant stimuli after breeding induction. Within couples, we quantified changes in calling dynamics and local field potential (LFP) activity in NCM. Both, males and females replied vocally stronger towards each other whereas females not only replied faster to their partner after the modification, but also increased their LFP neural response to specific calls. Performing long-term neural and vocal recordings of freely behaving animals while mimicking a natural environmental change, we uncover sex-specific and context-dependent vocal and neural changes that can be of major relevance for understanding general processes of vocal communication and reproduction.

P1-77 ADREANI, MN*; MENTESANA, L; GUEDES , E; CAVALLI, E; Max Planck Institute for Ornithology; *mnadreani@orn.mpg.de*

Aggressive Behaviour Induces Oxidative Stress in a Duetting Suboscine

Although aggressive phenotypes can have important implications on individual fitness, they also have the potential for generating trade-offs. Understanding their costs and their proximal causes will help us to better understand the evolutionary processes shaping aggression. Oxidative stress (OS) is a physiological imbalance between oxidant and antioxidant molecules in favor of the former, which can generate damage to proteins, lipids and DNA. Here we present the results from experiments of simulated territorial intrusion (STI) in the rufous hornero (*Furnarius rufus*) that were designed to test whether aggressive behavior can induce OS. We performed the STIs during the fertile period of the females using a dummy and intra-specific playbacks. Treated birds (18 males and 9 females) were exposed to the intrusion for 20 minutes, whereas control birds (24 males and 7 females) were captured immediately after playback started. We then collected a blood sample to measure three commonly used oxidative stress markers: one marker of oxidative damage (dROMs) and two markers of antioxidant capacity (OXY and GPX). Compared to control birds, males and females decreased their OXY capacity after the STI with females showing a more accentuated decrease. Furthermore, in females, aggressiveness parameters explained the OXY levels during the STIs. In males and females ROMs and GPX did not change after the intrusion. These results show that in the rufous hornero an aggressive interaction of 20 minutes is enough to elicit a change in the oxidative status, and that females are more sensitive than males. Overall, we discover for the first time that aggression can induce OS and provide novel insights about a sex-specific mechanism that could potentially explain differences in aggressive behaviour.

130-3 AGAN, JW*; LOVERN, MB; GRINDSTAFF, JL; FOX, SF; Oklahoma State University; *justin.agan@okstate.edu*

How Orange Bars in Juvenile Male Collared Lizards, Crotaphytus collaris, May Affect Their Fitness

Sexual selection is a powerful means to explain sexually dimorphic traits in animals. Often, the exaggerated dimorphic trait helps the bearer win male-male aggressive interactions. The collared lizard, *Crotaphytus collaris*, is no exception. These are sexually dimorphic lizards in multiple adult traits; color and body size are two. Even as juveniles, though, lizards are sexually dichromatic since males bear prominent lateral orange bars through their first season. Adults use their dimorphic traits to guard mates and defend territories from rival males to increase fitness. Juvenile males mimic the behavior of adults by being aggressive toward other juvenile males and they use these orange bars in this aggressive context. The orange bars allow for sexual discrimination in juvenile males and may also play a role in signaling aggressiveness of the bearer. Behavioral trials isolating the effect of orange bars from aggressive behavior show the bars and aggressive behavior are linked and that missing one, either the bars (the signal) or the aggression (the behavior), will decrease a lizard's effectiveness during male-male interactions. While lizards with increased aggression via hormone implants were significantly more aggressive in comparison to non-implanted stimulus lizards, lizards with only enhanced orange bars saw the opposite effect. When the orange bars are enhanced without the associated behavior appropriate for a strong signal, rival males retaliated against the "cheater" male. This means signal honesty would likely be socially enforced and that variation in the orange bar signal could affect fitness of juveniles by sorting which lizards are relegated to less suitable habitats and which remain in better ones.

P3-189 AGOSTO, LM*; BENTLEY, V; HELM, BR; HOLTHUSEN, J; RINEHART, JP; YOCUM, GD; GREENLEE, KJ; BOWSHER, JH; UCF, Orlando, FL, Aurora Univ., Aurora, IL, NDSU, Biological Sciences, Fargo, ND, USDA-ARS Animal Metabolism, USDA-ARS Insect Genetics and Biochemistry, NDSU, Biological Sciences, Fargo, ND; *bryan.r.helm@ndsu.edu*

Physiological and molecular regulation of metamorphic commitment in the solitary bee Osmia lignaria

The insect body size model hypothesizes that larval growth and metamorphosis are the developmental basis for adult size variation. Recent studies have suggested that these mechanisms may hold common elements among different taxa, while also diversifying as life histories evolve. However, the mechanisms must be characterized at different levels to model body size variation for each species. Recently, metamorphosis in the blue orchard bee, *Osmia lignaria*, was observed to undergo metamorphosis in response to food absence; however, the physiological and molecular mechanisms that regulate metamorphosis have not been described. We characterized hemolymph titers of juvenile hormone III (JH III) in developing *O. lignaria* using HPLC-MSMS from larvae that were feeding (days 5-12) and from larvae that had food removed (0-96 hrs, 8 time points). Gene expression of hormone synthesis and receptivity genes were characterized using qPCR. Hemolymph JHIII concentration decreased following food removal, although remained detectable for up to 72 hrs following food removal. Gene expression overall showed a significant shift between 12-24 hrs following food removal. In particular, JHIII genes (met, jhamt), ecdysone genes (ecr, shadow), and downstream transducers of hormonal signals (krh1, brc) were upregulated. These responses provide evidence that food removal induces metamorphosis in O. lignaria. However, JH synthesis and receptivity genes were upregulated following food removal as JHIII titers declined, which suggests that the relationship between physiological and molecular regulators are more complex than JHIII titer alone.

P1-273 AHLHOLM, PD*; MOUNTCASTLE, AM; Bates College; *pahlholm@bates.edu*

Effect of collision speed on rate of wing wear in Bombus impatiens bumblebees

Many flying insects accumulate progressive, irreversible wing damage over their lifetimes, which can have severe consequences for the animal, including reduced maneuverability and increased risk of mortality. Prior work has shown that the number of collisions with vegetation during foraging activity affects the rate of wing wear in bumblebees. However, little is known about how collision speed, or wingbeat frequency, affects rate of wing wear. To explore this relationship, we used a high-speed motor to induce damage in the wings of *Bombus impatiens* bumblebees, by forcing them to repeatedly collide with a leaf surface 500,000 times. We spun wings at three different speeds, representing the maximum rotational velocities associated with wingbeat frequencies of 150Hz, 200Hz and 250Hz, which encompass the range of frequencies observed in *B. impatiens*. Each wing was photographed at intervals of 50,000 collisions, and we measured the wingtip area remaining at each interval. Wings spinning at the fastest speed, associated with the highest wingbeat frequency, experienced a higher rate of area loss per collision, and a greater overall area loss, than those spinning at slower speeds. Our results suggest that rate of wing wear is dependent on wingbeat frequency, raising the possibility that wing damage risk may exert an evolutionary selective pressure on wing morphology that varies with wingbeat frequency, and perhaps even body size - which is itself correlated with wingbeat frequency.

S2-9 AHN, A.N.*; KONOW, N.; TIJS, C.; BIEWENER, A.A.; AHN-ROS, Anna; Harvey Mudd College, UMass Lowell, Harvard University, Harvard University; *aahn@hmc.edu*

In vivo length changes in relation to intrinsic physiological properties in vertebrate skeletal muscles

Segments of vertebrate muscles contract heterogeneously under *in vivo* conditions and may also operate on different regions of their force-length relationships. To examine this idea, we measured adjacent central and distal segment strain patterns *in vivo* in the semimembranosus muscle of the American Toad (*Bufo americanus*) during hopping and in the sternohyoid muscle of the rat (*Rattus rattus*) during chewing, as well as *in vivo* strain patterns of the proximal and distal fascicles of the pennate medial gastrocnemius muscle of the rat during running. On the same day, we compared the *in vivo* lengths measured to their respective *in vitro* or *in situ* force-length properties. Within a fascicle, the adjacent central and distal segments of the frog semimembranosus and rat sternohyoid muscles shorten and lengthen heterogeneously *in vivo*. *In vitro* or *in situ*, the central muscle segments of both frog jumping and rat chewing muscles operated on the plateau region of their force-length relationships while the distal segments operated on the ascending limb of their force-length relationships. The ascending region provided stability for the sarcomeres in the distal segments. Two adjacent segments can operate on different regions of their force-length relationships simultaneously both *in vivo* and *in vitro*. By contrast, both proximal and distal fascicles of the rat medial gastrocnemius muscle operated on the ascending region of their force-length relationships with minimal *in vivo* strain differences between the fascicles, suggesting uniform fascicle strain behavior through the muscle. Understanding regional differences within muscles *in vivo* will allow us to link our understanding of sarcomere behavior with whole muscle behavior during movement.

P1-114 AHUJA, N*; BABONIS, L; MARTINDALE, M/Q; Whitney Lab for Marine Bioscience, Whitney Lab for Marine Bioscience ; *nafun247@gmail.com*

Cnidocyte development and morphology in Nematostella vectensis

A distinguishing cell type in cnidarians is the cnidocyte. Previous studies of cnidogenesis indicate that the same progenitor cell gives rise to cnidocytes and neurons. The differences between neurons and cnidocytes can be investigated by examining gene expression for specific cell types. *Hydra*, a well-studied animal for cell differentiation, has been a useful model for cnidogenesis, but little is known about cnidogenesis in other cnidarians. Minicollagen, a novel protein, is the main protein responsible for the structural elements of the mature cnidocyte. Using immunohistochemistry and in situ hybridization, we examined the expression of candidate genes for cnidogenesis in wild type embryos to verify if the same genes in *Hydra* are present in *Nematostella*. ZNF845, a gene present in Interstitial cells in *Hydra*, plays a role in cnidocyte development. To understand ZNF845's role in cnidogenesis in *Nematostella*, we injected embryos with a ZNF splice-blocking morpholino. Knockdown of ZNF845 resulted in both a decrease in the quantity of cnidocytes and number of cells expressing three putative cnidocyte-specific transcription factors: nanos, mef2 and NR12 (COUP-TF). To understand cnidocyte structure and regulation, we manipulated the expression of three minicollagens using translation-blocking morpholinos. Using DAPI staining to detect mature cnidocytes, we confirmed a lack of mature cnidocytes in these treatments. In situ hybridization of minicollagen knockout embryos shows no compensation for the loss of minicollagen proteins by the cnidogenesis pathway, since no significant differences in expression of cnidocyte-specific transcription factors were found. These results suggest that in *N. vectensis*, ZNF845 is upstream in cnidogenesis and that all three minicollagens are necessary for normal cnidocyte development.

S5-1 AIELLO, BR*; GILLIS, GB; FOX, JL; University of Chicago, Mount Holyoke College, Case Western Reserve University; *braiello@uchicago.edu*

Sensory feedback and animal locomotion: perspectives from biology and biorobotics: An introduction to the symposium.

The locomotor appendages of animals, from insect wings to tetrapod limbs, perform dual roles as sensors and propulsors, and sensory feedback has been shown to be critical to an animal's motor performance. This symposium brings together researchers using novel techniques to study how different stimuli are encoded, how and where multimodal feedback is integrated, and how feedback modulates motor output in diverse modes of locomotion (aerial, aquatic, and terrestrial) in a diverse range of taxa (insects, fish, tetrapods), and in robots. Similar to the limbs of biological organisms, the limbs of robots can be equipped with integrated sensors and can rely on sensory feedback to adjust output signals. Engineers often look to biology for inspiration on how animals have evolved solutions to problems similar to those experienced in robotic movement. Similarly, biologists too must proactively engage with engineers to apply computer and robotic models to test hypotheses and help answer questions on the capacity and roles of sensory feedback in generating effective movement. Through a diverse group of researchers, including both biologists and engineers, this symposium will catalyze new interdisciplinary collaborations and identify future research directions for the development of bioinspired sensory control systems, as well as the use of robots to test hypotheses in neuromechanics.

S5-5 AIELLO, BR*; OLSEN, AM; MATHIS, CE; WESTNEAT, MW; HALE, ME; Univ. of Chicago; *braiello@uchicago.edu*

Fins, function, and physiology: the role of pectoral fin mechanosensation during swimming

Mechanosensory feedback is critical to the motor performance and fine control of appendages in animals. In fishes, the pectoral fin is outfitted with mechanosensors that sense ray bending and it functions as a propulsor. During propulsion fishes modulate thrust and efficiency by finely control the shape of their fins. Here we examine the control of fin shape and movements by integrating previous work on afferent physiology with new data on fin kinematics and motor patterns. We hypothesize that sensory input from fin ray afferents modulates motor output and the fine movements of the fins. To test these ideas, we examine how the loss of pectoral fin ray sensation impacts muscle activity patterns and kinematics during labriform swimming in a parrotfish, *Scarus quoyi*. In the intact fish, the basic motor pattern is alternating activity of the antagonist abductor and adductor groups. Bilateral transections of all sensory nerves that innervate the pectoral fin rays resulted in increased fin beat frequency and a transition to the body-caudal fin gait at slower speeds. 3D kinematics reveals that the trajectory of the fin resembles a figure eight in control fish, and the anteroposterior translation and twisting of the fin is reduced after transection. The duration of muscle activity was significantly greater after transection, which we suggest enhances control and stability after sensory loss through the co-contraction of antagonistic muscles. To more deeply explore the feedback loop of fin shape impacting activity of fin ray afferents, which modulates fin movements, we additionally examine neural encoding of fin bending in relation to typical and post-nerve transection motor control patterns and movements.

S5-7 AKANYETI, O*; LIAO, JC; Aberystwyth University, University of Florida; *ota1@aber.ac.uk*

The Interplay between Locomotion and Lateral Line Sensing in Swimming Fishes

The lateral line system of fishes is one of the most elaborate and ancient sensing architectures found in nature. It consists of mechanoreceptors distributed around the body which provide information on local flows and pressure gradients. Neurophysiological and theoretical studies have revealed important insights into the function and capabilities of individual receptors, while organismal studies have taken advantage of pharmacological treatments to ablate the lateral line system in order to interpret its function during critical behaviours such as rheotaxis, predator evasion, prey tracking and obstacle avoidance. What remains missing is an integrated view on how hydrodynamic information is organized around swimming fishes. During swimming, extracting meaningful information from local flows is challenging because fish must be able to distinguish between an external stimulus and a stimulus generated through its own movements. Here, we leverage a combination of robotics, modelling, and biological experiments to investigate what information is available to the distributed architecture of the lateral line; specifically, how head morphology and swimming movements affect the organization of this information. Our initial efforts focus on the 3-dimensional fluid-structure interactions around the head of rainbow trout (*Oncorhynchus mykiss*), which has an intriguing canal pattern compared to the body. Our results show that 1) there exist sub-regions within the cranial lateral line system that are uniquely sensitive to different hydrodynamic stimuli, 2) the shape and surface topography of the fish head act like a hydrodynamic antenna to enhance lateral line sensing, and 3) sensing volume and frequency response of the head changes dynamically with the swimming patterns of the fish. Our findings promise to provide novel design principles for distributed sensing systems in underwater robotics.

P3-179 ALBERTO, A.A.*; GARLAND JR., T; FREEMAN, P. A.; University of California Riverisde, University of Nebraska Lincoln; *acast059@ucr.edu*

Evolution of Hindlimb Bone Dimensions and Muscle Masses in House Mice Selectively Bred for High Voluntary Wheel-Running Behavior

We have used selective breeding with house mice to study coadaptation of morphology and physiology with the evolution of high daily levels of voluntary exercise. Here, we compared hindlimb bones and muscle masses from the 11th generation of four replicate High Runner (HR) lines of house mice bred for wheel running with four non-selected control (C) lines. Mass, length, diameter, and depth of the femur, tibia-fibula, and metatarsal bones, as well as masses of gastrocnemius and quadriceps muscles, were compared by analysis of covariance with body mass or body length as the covariate. Mice from HR lines had relatively wider distal femurs and deeper proximal tibias, suggesting larger knee surface areas, and larger femoral heads. Sex differences in bone dimensions were also evident, with males having thicker and shorter hindlimb bones when compared with females. Several interactions between sex, linetype, and/or body mass were observed, and analyses split by sex revealed several cases of sex-specific responses to selection. A subset of the HR mice in two of the four HR lines expressed the mini-muscle phenotype, characterized mainly by an ~50% reduction in hindlimb muscle mass, caused by a Mendelian recessive mutation, and known to have been under positive selection in the HR lines. Mini-muscle individuals had elongated distal elements, lighter and thinner hindlimb bones, altered 3rd trochanter muscle attachment positions, and thicker tibia-fibula distal widths. Finally, several differences in levels of directional or fluctuating asymmetry in bone dimensions were observed between HR and C, mini- and normal-muscled mice, and the sexes. This study demonstrates that skeletal dimensions and muscle masses can evolve rapidly in response to directional selection on locomotor behavior.

37-6 ALBUQUERQUE, RL*; ZANI, PA; GARLAND JR., T; Univ. of California, Riverside, Univ. of Wisconsin-Stevens Point; *ralbu001@ucr.edu*

Predictors of sprint speed and maximal aerobic capacity (VO_2max) in the lizard Sceloporus occidentalis.

The ecomorphological paradigm recognizes that lower-level subordinate traits (e.g. enzyme activities at the cellular level, limb proportions) affect organismal performance abilities (e.g., maximal sprint speed), these performance traits constrain behavior, and behaviors impinge on life history traits and hence Darwinian fitness. Few studies aimed at testing these ideas have been able to examine all levels in this hierarchy. As a step towards that goal, we examined key lower-level morphological and physiological traits, two aspects of organismal performance, and indicators of field locomotor behavior in ~40 adult male *S. occidentalis* from Hampton Buttes, OR, during the breeding season. We measured lower-level traits (blood [hemoglobin] & hematocrit; heart, liver, lung, thigh & calf muscle masses; hind & fore limb spans; tail length; number of ticks), performance (maximal sprint speed, aerobic capacity), and field behavior (displays, distance, moves per minute). Where appropriate, residuals from regressions on body mass were analyzed. Some of the lower-level traits were significantly ($P<0.05$) intercorrelated, e.g., hematocrit and hemoglobin ($r=0.9$), and both correlated with heart mass ($r=0.6$ and 0.5, respectively). Multiple regression revealed residual hemoglobin concentration ($b=0.51$) and residual calf muscle mass ($b=0.37$) as significant predictors of residual VO_2max and speed, respectively, consistent with previous theoretical and empirical studies. However, neither VO_2max nor speed were correlated with any behavioral trait, which suggests that the measured aspects of movement and display intensity are not limited by those performance capacities.

P2-73 ALFARO, G*; HARFUSH, M; CROCKER, D; Sonoma State University, CA, Centro Mexicano de la Tortuga, Mexico; *arangob@sonoma.edu*

Physiological Analysis on the Diving Capacity of the Olive Ridley Sea Turtle, Lepidochelys olivacea

Sea turtles are air-breathing divers that have been documented to dive on inhalation. Despite the importance on the diving capacity for a sea turtle, allometric data on their diving ability is very limited, to the sole documentation of lung size relative to mass. For a more complete understanding on their diving physiology, previous studies have suggested the analysis of blood and tissue oxygen storages to investigate the possibility of a trade off between lung size and blood/tissue oxygen storages. The aim of this study was to create baseline parameters of the diving physiological adaptations that enable sea turtles to stay underwater for long periods of time, which is currently lacking in the scientific literature. To test this hypothesis, wild females of *Lepidochelys olivacea* (n=10), were used to collect blood samples as to establish plasma volume, hemoglobin, hematocrit, mean corpuscular hemoglobin value, and total blood oxygen stores. Our preliminary results provides a starting point into subsequent analysis of muscle oxygen stores that will be complemented, along with lung oxygen storages to calculate total body oxygen storages for this specie. This study also extends our knowledge into the diving adaptations that enable sea turtles to potentially increase foraging time; although it has been noted that a greater diving capacity also enhances migration and mating success, and reduces predation, by limiting their time at the surface.

P3-267 ALFONSO, YU*; NUNEZ, LP; FONG, A; TORRES, J; Division of Herpetology, Florida Museum of Natural History, Univ. of Florida, Gainesville, Centro Oriental de Ecosistemas y Biodiversidad (BIOECO), Museo de Historia Natural "Tomas Romay", Santiago de Cuba, Cuba, Department of Ecology and Evolutionary Biology, The University of Kansas, Lawrence; *anoles1983cuba@gmail.com*

Evolutionary history of the Antillean gecko Tarentola americana (Phyllodactylidae) based on mitochondrial and nuclear DNA sequences

The genus *Tarentola* (Family Phyllodactylidae) comprises 31 species distributed across the Mediterranean Basin and on many Macaronesian islands, including Madeira, the Selvages, the Canary and Cape Verde islands. In the New World, three species are recognized as representative of the subgenus Neotarentola: *Tarentola americana* (Cuba and the Bahamas), *T. albertschwartzi* (the largest and probably extinct) from Jamaica, and the recently described *T. crombiei* (Cuba). Earlier phylogenetics analysis in the Cuban *Tarentola* suggest 11.4 (7.2-15.2) Ma for the split between *T. a. americana* and *T. crombiei* and 5.5 (2.8-9.1) Ma for the split between the central and eastern Cuban populations of *T. a. americana*. Previous data indicate a long occupation and diversification (~15 million years) of this genus of geckos on Cuba. In the present work we have re-examined the phylogenetic and phylogeographic relationships between *T. a. americana*, *T. crombiei* and we included the Bahamian taxon *T. a. warreni*. We have investigated the sequence variation of three mitochondrial genes (12S rRNA, 16S rRNA, and cytochrome b), and one nuclear gene (amelogenin) for 22 populations reaching their geographic distribution. The phylogenetics results obtained for population of *Tarentola amaricana* between Cuba (eastern and western) and Bahamas provide deep split between them and may warrant recognition as a separate species, after further morphological study.

P3-48 ALI, RS*; WELCH, KC; University of Toronto; *raafay.ali@mail.utoronto.ca*

Glucose Transporter Regulation in Response to Recently Ingested Carbohydrate in the Ruby-throated Hummingbird, Archilochus colubris.

Ruby-throated hummingbirds (*Archilochus colubris*) power energetically expensive behaviour almost entirely with recently ingested carbohydrates. When fasting, hummingbirds are capable of supporting metabolism entirely with endogenous fatty acid oxidation. Within 20-30 minutes of the start of foraging on floral nectar hummingbirds, can switch to fueling their metabolism entirely with ingested sugar. This rapid and complete fuel switch implies high capacities for sugar uptake and delivery to active tissues. Their enlarged heart, high heart rate, high vascularisation, and fast-acting digestive, glycolytic, and oxidative enzymes all contribute to rapid transport and breakdown of fuel. Less understood is the transmembrane transport of carbohydrates, regulated by the SLC2 family of hexose transporters, the glucose transporters (GLUTs) and their potential role in regulating this fuel switch. Hummingbirds lack insulin-responsive GLUT4 and don't exhibit an insulin-mediated blood glucose response. Thus, other GLUT isoforms (e.g. GLUT1, 2, 3, and 5) must play a key role in blood sugar regulation and high tissue uptake capacities in hummingbirds. Using an imunohistochemical approach, we are characterizing subcellular localisation of *A. colubris* GLUTs in several tissues in response to availability of carbohydrates. We hypothesize that carbohydrate ingestion will increase co-localisation of GLUTs 1, 2, 3, and 5 with the cell-surface membranes within 20-30 minutes and decrease when fasted. This may provide an insight into a unique glucose sensing and hexose-regulating system that both operates at a rapid pace and is also insulin independent.

113-4 ALLEN, PE*; CUI, Q; MILLER, CW; University of Florida; *pabloallen@ufl.edu*

Adaptive plasticity and genetic differences in mouthpart length across a broad landscape in a cactus-feeding bug

Phenotypic plasticity is important for organisms facing heterogeneous environments because it can allow them to quickly respond to changing or novel conditions and persist. Thus, phenotypic plasticity can act as a bridge until adaptive genetic changes occur. However, this early, critical stage in the process of adaptation has been hard to identify. Patchy but widely distributed species are good candidates to study the process of adaptation. Developmental responses in mouthpart shape and size may allow immediate use and rapid, whole-organism adaptation to changing resource availability, but it may also lead to within species genetic differences across populations that use resources of varying sizes. Combining fieldwork with common garden/reciprocal transplant experiments, we examined the response of mouthpart length across a broad landscape in the leaf-footed cactus bug *Narnia femorata*. These insects feed with straw-like mouthparts (=beak) through the fruit wall to get to the seeds and pulp. Here, we present evidence of genetic and developmental plasticity in mouthpart length in response to food resources of different sizes. Bugs that locally feed on cacti species with thicker fruits have genetically longer mouthparts, but both populations studied in the common garden also exhibit patterns consistent with adaptive plasticity.

S7-3 ALLEN, LC*; CHAR, C; WRIGHT, T; HRISTOV, NH; MERSON, M; Winston-Salem State University, Char Associates, TERC, TERC; *allenl@wssu.edu*

Beyond the Brown Bag: Designing Effective Professional Development for Informal Educators

Most researchers are keenly interested in finding new ways of disseminating their work beyond traditional publication routes. Informal educators who interact daily with the public are interested in learning more about mission-relevant scientific research, and see their role as translating science for visitors to increase the public's intellectual and emotional connections with the natural world. A common form of contact between scientists and public-educators involves a researcher giving a one-time (~1hr) research talk to a group of these educators, with the implicit hope that certain science messages will get incorporated into their interactions with visitors. Unfortunately, this approach leaves the conscientious informal educator with insufficient resources for developing interpretive opportunities for the public. Barriers include: gaps in knowledge, limited scientific background for grasping short lectures or publications designed for science researchers, and limited access to publications. This paper will explore opportunities for scientists to establish mutually beneficial relationships with informal educators to increase the broader impacts of their work. Our proposed model of professional development involves a more balanced partnership where scientist and educators work together to tease out the relevance to public audiences and develop programs about the science. Results from surveys, and interviews indicate that both sides of this partnership benefit from extended contact. The session provides specific techniques and ideas that will support productive ways to collaborate with informal educators and promote the visibility of scientific research to public audiences.

P2-272 ALMANZAR, A*; WARKENTIN, KM; Boston University; *almanzar@bu.edu*

How development changes escape-hatching success in snake attacks: a video analysis of red-eyed treefrog embryo behavior and performance

Agalychnis callidryas lay eggs over Neotropical ponds and their tadpoles fall into the water upon hatching. Arboreal snakes consume many eggs, but some embryos escape by hatching rapidly during attacks. Snake-induced hatching begins at age 4 days, then escape success improves and becomes more consistent as embryos develop. To elucidate how and why escape success changes, and the role of embryo decisions and hatching performance, we recorded video of snake attacks on embryos of different ages. We caught two common species of nocturnal egg-eating-snakes (*Leptodeira septentrionalis* and *Imantodes inornatus*) from a pond in Panama, kept them in terraria under natural temperature, humidity, and photoperiods, and offered them egg clutches of different developmental stages. We used 4K infrared cameras to record macro-video, enabling detailed analysis of individual embryo behaviors. Escape success varied widely, from 0-100% across embryonic ages 3-6 days. Initial analysis suggests that, once embryos can sense vibrations, changes in hatching decisions may affect escape success more than do changes in hatching performance. Development appears to increase the likelihood that embryos will hatch preemptively, in response to indirect vibrations from attacks on clutch-mates, rather than waiting for direct snake contact with their own egg. Such preemptive hatching appears to increase escape rates, although some directly attacked embryos do escape. Further analysis of the videos will examine relationships between hatching decisions, hatching performance, and embryo fates in snake attacks across development through the plastic hatching period. This will contribute to our understanding of the development of embryo behavior and its effect on survival in predator-prey interactions.

136-5 ALONSO, V*; DILLMAN, AR; Univ. of California, Riverside; *valon001@ucr.edu*

Morphological changes of insect-parasitic nematodes in response to different host-tissues.

Entomopathogenic nematodes (EPNs) are insect-parasites that typically kill their hosts within 48 hours of infection and have been used in the biological control of insects. When free-living infective juveniles (IJs) infect a host, they release their bacterial symbiont, and undergo notable morphological changes such as shedding of the cuticle, opening of the mouth, and expansion of their pharyngeal bulb. All of these characteristics can classify an IJ as "activated", which describes the initial process of transitioning into an active parasite. These EPNs are known to infect and kill different hosts at varying rates. Studying how EPNs activate in different hosts can help us better understand the intricacies of parasitism, host preference, and the initiation of parasitism. Here we investigated EPNs from the genus Steinernema, and quantified their levels of activation based on morphological changes. We found that nematode activation is context dependent, and that IJs that have recently emerged are less likely to activate than IJs that have emerged after a longer period of time.

136-7 ALPERT, JN*; SCHAFER, JL; TRINGALI, A; BOWMAN, R; William Jewell College, Department of Biology, Liberty, MO, USA, Archbold Biological Station, Avian Ecology Laboratory, Venus, FL, USA., Archbold Biological Station, Avian Ecology Laboratory, Venus, FL, USA.; *alpertj@william.jewell.edu*

Factors influencing neophobia and its short-term repeatability in the Florida Scrub-Jay (Aphelocoma coerulescens)

Neophobia is the fear and avoidance of novel objects. This trait is correlated with other traits, such as boldness (or shyness), tolerance of environmental changes, risk avoidance, territorial defense or exploration, thus forming individual behavioral syndromes and personalities, which are repeatable traits over the life of an an individual. The Florida Scrub-Jay (*Aphelocoma coerulescens*, hereafter FSJ) is a Federally Threatened species endemic to Florida, relying on post-fire successional stages in xeric oak scrub. Due to its longevity, the FSJ experiences a wide range in post-fire succession, thus habitat structure. Our goals were to examine how neophobia varies relative to successional stage and factors that influence its short-term repeatability. We conducted this research at Archbold Biological Station in Lake Placid, Florida where each FSJ is trapped and banded at approximately 65 days post-fledging. We assessed latency to enter a baited trap one day after being banded. We then performed neophobia trials, giving each jay 600 seconds to approach a novel object with a food reward. We repeated trials for 36 individuals from 19 territories when juveniles were between 75 and 85 days old. We measured latency to enter the arena at different distances from the novel object and latency to take a food reward. Latency in neophobia trials was not correlated with latency to approach a baited trap, suggesting that neophobia and fear are distinct behavioral responses. Results of neophobia trials were not repeatable and we also found no association between habitat structure and neophobia.

P2-268 ALTO, SI*; STROTHER, JA; Oregon State University; *altos@oregonstate.edu*

Effects of elevated environmental CO_2 on the swimming kinematics of zebrafish larvae (Danio rerio)

Most teleost fishes sense environmental O_2 and CO_2 levels using neuroepithelial cells (NECs) distributed across the gill filaments. Afferent signals from these cells are critical for the regulation of swimming activity, heart rate, ventilation, and vascular resistance. Although cardioventilatory control has been well studied in adult fishes, much less is known about how larval fishes respond to respiratory cues. Previous studies have found that zebrafish larvae express NECs as early as 5 days post-fertilization (dpf), and that hypoxia induces changes in swimming patterns, increased heart rate, and hyperventilation. In this study, we examined the behavioral responses of zebrafish larvae to elevated environmental CO_2. Behavioral responses were recorded by imaging the animal from two orthogonal perspectives, and performing automated reconstruction of the trajectory and midline kinematics of the larvae. This dataset was used to calculate percent time swimming, swimming speed, and position in the water column. We found that elevated environmental CO_2 has a number of effects on swimming patterns, including a notable decrease in the swimming speed. High environmental CO_2 reduces the blood-water diffusion gradient, and therefore reduces the rate at which CO_2 is released. Decreasing behavioral activity may reduce metabolic rate and allow fish larvae to compensate for a limited ability to expel CO_2.

42-6 ALVARADO, SG*; BASHIER , R; BYRNE, A; BLAKKAN, D; LEE, G; FERNALD, RD; Stanford University, Palo Alto; *salvarad@stanford.edu*

Blue fish, yellow fish, same fish: The epigenetic regulation of endothelin signalling contributes to yellow and blue coloration of male A. burtoni color morphs

Dynamic coloration is an important trait across the animal kingdom as it aids in concealment and social communication. In cichlid fish, body coloration is a particularly important trait that has driven sexual selection between conspicuously colored males and cryptic females. In males of *Astatotilapia burtoni* fish can be one of two reversible color morphs that are accompanied with different social outcomes . While many reports provide support for the role of genetics in developmental coloration, little remains known about how such static substrates become plastic in response to various environmental stimuli. Epigenetic mechanisms, such as DNA methylation, provide dynamic substrates capable of altering gene function. DNA methylation involves transcriptional silencing through the covalent addition of a methyl moiety to cytosine residues in the promoter of a gene. Here, we provide evidence supporting the role of DNA methylation in regulating color changes in *A. burtoni* males. We measured molecular changes to transcription and DNA methylation in candidate regulators of pigmentation in male *A. burtoni* transitioning between color morphs. Following this screen we revealed reversible DNA methylation at a single CpG dinucleotide within *endothelin receptor B* (*EdnRB*). Pharmacological manipulation of EDNRB resulted in a cell-specific aggregation of yellow chromatophores in fish fin tissue. Taken together, we provide support suggesting that DNA methylation tunes coloration within *A. burtoni* by sensitizing yellow chromatophores to endogenous endothelins.

P1-105 AMATO, V*; PATTON, ST; LOPEZ, J; KHALIL, J; BEAGHLY, T; RAFTERY, LA; GIBBS, AG; Univ. of Nevada, Las Vegas; *allen.gibbs@unlv.edu*

Life History Tradeoffs in Starvation-Selected Drosophila

We selected for adult resistance to starvation in replicated populations of *Drosophila melanogaster* for ~100 generations. Starvation-selected (S) flies contained over twice as much lipid as fed control (F) populations, contributing to their higher starvation resistance. Lipid accumulation occurred during an extended larval feeding period. S flies eclosed 30 hours after F flies. Thus, selection on adult performance significantly affected pre-adult physiology. We also investigated whether increased allocation of resources to somatic energy storage affected reproductive success. In wild-type females, the larval fat cells undergo programmed cell death within 24 hours, and fat body resources are transferred to the rapidly growing ovaries. Despite higher lipid contents at eclosion, ovaries of S females were smaller and grew more slowly than F ovaries. Consistent with these results, S females had 30% lower fecundity and 20% fewer ovarioles. Ovariole number is determined during larval development, again indicating that adult starvation selection has altered larval development. Supported by IOS-1355210 from NSF and R15-GM100395 from NIGMS.

32-2 AMATO, CM*; BOYD, M; MCCOY, KM; East Carolina University; *amatoc13@students.ecu.edu*

Early Vinclozolin exposure increases the severity of penile abnormalities

Hypospadias occurs when the urethra exits ventrally along the penis, rather than the distal tip. Hypospadias is second most common birth defect in the US and exposure to endocrine disrupting chemicals is strongly associated with hypospadias incidence. Normal penis development is tightly controlled by endogenous androgens produced by the testes. Disruption of androgen dependent signaling during this masculinization window alters several aspects of penile development and results in feminization of the penis. Both humans and rodents exhibit a continuous range of hypospadias severity, but the mechanisms that drive this variation are not well known. To begin to understand the drivers of hypospadias severity, we must understand the developmental timeline for initiation of genital masculinization. Previously studies document E13.5 androgen signaling to be non-essential for proper penis development. To determine how dose and timing of androgen signaling antagonism affects hypospadias severity CD1 mice were separated into 2 dosing groups. Mice exposed an earlier dosing window received corn oil control (CO), 75, 100, 125, and 150 mg/kg of vinclozolin on embryonic days (E) 13.5-16.5. Mice exposed to the later dosing window received the same doses on E14.5-16.5. To test if effects were due to the timing of exposure or total dose we also dosed with 200 mg/kg for the four-day window. This design allows us to evaluate the importance of anti-androgen exposure timing versus the total amount of antiandrogen exposure for altering hypospadias severity. We find that blocking androgen when at the time it is produced increases the potency of the androgen antagonist. This suggests that E 13.5 is a critical day that primes the genitalia to respond to testosterone signaling later in development.

P3-41 AMBROSE, AF*; ZUEVA, O; MASHANOV, V; Savannah State University, University of North Florida; *alexandria.ambrose13@gmail.com*

Cell Proliferation in the Regenerating Arm of the Brittle Star Ophioderma brevispinum

Echinoderms are well known for their ability to regenerate amputated or autotomized body parts. Regeneration in this phylum is still poorly understood at the mechanistic level. A key part of post-traumatic tissue growth is cell proliferation. Here, we characterized the dynamics of cell division in the regenerating arm of the brittle star *Ophioderma brevispinum*. Over the 30 day-long observation period, *O. brevispinum* was able to regrow a significant portion of the autotomized arm. The regenerated arm segments fully restored all anatomical components. The peak of cell proliferation in all arm tissues (epidermis, coelom, radial nerve cord, water vascular canal and the mesenchyme) occurred synchronously on day 5 post-injury. The dynamics of cell division determined by S-phase labeling with EdU corresponds to the temporal pattern of cyclin B expression. We conclude that (a) all anatomical components of the regenerating arm originate from the corresponding tissues of the stump rather than from a set-aside population of multipotent pluripotent cells, (b) there must be a signaling mechanism that synchronizes cell proliferation across the tissues of the regenerating arm.

P1-255 AMPLO, H/E*; FLAMMANG, B/E; Rutgers University, Newark, New Jersey Institute of Technology; *hea7@njit.edu*

Picky Placement: A Study of Remora Attachment

Remoras (Family Echeneidae) are commonly observed attached to a variety of hosts (e.g. sharks, turtles, and marine mammals) using a cranial adhesive disc derived from dorsal fin elements. Previous studies have focused on the functional morphology of the remora adhesive disc; however, limited research has been performed to determine if remoras have preferential adhesion locations on their hosts, or if attachment position is random and opportunistic. Here we investigate remora attachment locations on sharks, billfish, turtles, baleen whales, dolphins, and manatees. Using a morphologically anchored grid based on general anatomical features shared by the range of host organisms, we established frequency of attachment along positions on the host bodies. The grid was applied to photographs and video documentation of remoras attached to host organisms to quantify zones of preferential adhesion. In future work, we will compare the locations of high remora density to computational fluid dynamics analysis of the host organisms to determine if there is a hydrodynamic benefit to attachment locations.

P2-112 AMUNDSON, LM; California Academy of Sciences; *laurenamundson2884@gmail.com*

A phylogenetic approach to assessing morphological and molecular divergence in ground beetles of genus Promecognathus (Coleoptera: Carabidae: Promecognathini)

The species is the most fundamental taxonomic unit and is useful in studies of conservation, biodiversity and ecological processes. Understanding the delimitations that classify a species can be challenging because there are so many parameters to be considered when applying these concepts. The following phylogenetic study examines the coleopteran genus *Promecognathus* that is comprised of two species *P. crassus* and *P. laevissimus*. Using phylogenetic analyses we test the monophyly of these two species and their respective genetic exclusivity using three molecular markers: 18s rRNA, *wingless* nDNA and *COI* mDNA. This study confirms the distinctiveness of these species under three established species concepts as well as provides a framework for future phylogeographic analyses of the genus.

33-2 ANDERSON, RC*; ALI, SB; ANDERSON, Rindy; Florida Atlantic University; *rindy1@gmail.com*

Understanding Complexity in Communication Systems: Song and Aggressive Signaling in the Bachman's Sparrow

Male Bachman's sparrows (*Peucaea aestivalis*) have large vocal repertoires containing 35-45 song types and multiple categories of songs and calls. We examined the territorial defense function of the vocal repertoire of this species by quantifying singing behaviors and aggressiveness in response to a simulated territorial intrusion. We compared vocal and other behaviors between the intrusion and post-intrusion periods, compared more aggressive birds (attackers) with less aggressive birds (non-attackers), and tested for signals that predict attack. During intrusion, subjects switched among their song types at higher rates, and gave more "excited songs" and calls, however song switching and excited songs did not differ between more and less aggressive birds. These behaviors appear to serve an agonistic function but do not predict aggression. More aggressive birds gave more calls and sang more low amplitude "whisper songs." In line with previous studies of aggressive signaling in songbirds, Bachman's sparrows appear to use low amplitude song to threaten rivals. Based on our results, the Bachman's sparrow provides another species in which to test hypotheses about the evolution of quiet threat signals. The eavesdropping avoidance hypothesis predicts that other acoustic traits besides amplitude should be shaped by selection to minimize signal propagation and transmission range. In contrast to most species that use low-amplitude songs to threaten rivals, the whisper songs of Bachman's sparrows do not differ in acoustic structure from their broadcast primary songs, except for amplitude. This provides an opportunity to explore whether reduced amplitude is sufficient to reduce the costs of eavesdroppers, and to test alternative hypotheses to explain the use of low amplitude song as a threat.

44-1 ANDERSON, P; Univ. Illinois, Urbana-Champaign; *andersps@illinois.edu*

Fangs, Stingers and Spines: Common mechanical principles across biological puncturing tools

The field of comparative biomechanics explores how the laws of physics influence morphological variation and evolution. By basing biological inquiry on the level playing field of physics, it is possible to compare disparate organisms from different phyla based on how they overcome similar mechanical challenges. For example, a venomous snake injecting venom, a wasp using its stinger to oviposit eggs and a mantis shrimp spearing a passing fish are all performing a basic function: puncture. These examples involve different structures and behaviors, yet all must overcome the same mechanical challenge of creating fractures within the target to insert their tools. Given the commonality of mechanism, one would expect all these tools to have common morphological features necessary to maintain functional fidelity. In order to identify and assess these common morphological features, I compiled morphological data on the puncturing tools of over 100 animals and plants. The species list includes both vertebrates and invertebrates that puncture in different environments (air vs. water) and at different dynamic levels, from passive defensive spines to extreme high-speed puncture. Morphological data on the puncturing tool consists of biomechanical shape traits based on engineering theory, as well as observations from the archeological and ballistics literature. Biomechanical traits were compared amongst all groups, with special note made to comparisons between taxa with different ecologies and behaviors. Preliminary results reveal several patterns such as the aspect ratio of the tools being size-limited, while cross-sectional shape varies between aquatic and terrestrial environments. These results highlight common morphological patterns amongst disparate taxa based on both tool scaling and environment.

68-3 ANDERSON, R *; MCMAHON, Q; ANDERSON, Roger; Western Washington University; *Roger.Anderson@wwu.edu*

Food availability, feeding rate and body condition in desert lizards in contrasting climate conditions

Deserts are well known for among-year variation in climate and the strong effect of pulses of rainfall on community productivity. In the northern extreme of the Great Basin desert, three contrasting years (hot and dry, warm and wet, and intermediate conditions) provided a unique opportunity to compare the daily rate of feeding and body condition of lizards among those years. The hot and dry spring in one year was severe enough to cause lizards to skip reproduction in that year, whereas the unusually wet and warm (as opposed to wet and cool) provided the opportunity to compare presumably optimal conditions with not only the hot and dry year, but also with a year comprising average climate for that locality. Both sexes of the western whiptail lizard and the desert horned lizard performed similarly among years, but the feeding rate and body condition of both sexes of the long-nosed leopard lizard varied with productivity of prey. The food acquisition modes of these lizards and their prey types and prey availability are discussed in light of these contrasting physiomorphic responses.

P2-31 ANDERSON-BUCKINGHAM, S*; BAUER, C; FUDICKAR, A; ABOLINS-ABOLS, M; ATWELL, J; KETTERSON, E; GREIVES, T; North Dakota State Univ., Adelphi Univ., Indiana Univ., Indiana Univ.; *cbauer@adelphi.edu*

Differential expression of hypothalamic genes in juncos (Junco hyemalis) during gonadal development: implications for regulation of timing of breeding

Seasonally breeding birds must time their reproduction to match optimal environmental conditions. The transition into breeding condition and gonadal growth are regulated by the hypothalamic-pituitary-gonadal (HPG) axis at multiple levels. Our study focuses on the level of the hypothalamus and examines expression of candidate genes in relation to three potential mechanisms regulating gonadal recrudescence: 1) top-down stimulation and inhibition of the HPG-axis via gonadotropin-releasing hormone (GnRH) and gonadotropin-inhibitory hormone (GnIH), 2) sex steroid negative feedback sensitivity via androgen receptor (AR) and estrogen receptor alpha (ERα), and 3) sensitivity to stress hormones via glucocorticoid receptor (GR) and mineralocorticoid receptor (MR). We measured hypothalamic mRNA expression of these genes via qPCR in captive male Dark-eyed Juncos (*Junco hyemalis*) held under the same conditions but expressing different stages of gonadal recrudescence in early spring. All males were captured from the same overwintering population, but males from a resident subspecies were in a more advanced stage of gonadal recrudescence than males from a migratory subspecies. We found that residents had significantly higher mRNA expression levels of *GnRH*, lower levels of *AR* and *ERα*, and similar levels of *GR* and *MR*. These results suggest decreased hypothalamic sensitivity to sex steroid negative feedback and increased GnRH production as factors promoting gonadal recrudescence.

P1-199 ANTHONY, SE*; BUDDLE, CM; HøYE, TT; HEIN, N; BECKERS, N; SINCLAIR, BJ; Western University, McGill University, Aarhus University, University of Bonn; *santho2@uwo.ca*

Thermal limits of spiders, mites, and pseudoscorpions from Arctic and temperate habitats

Arachnids live in most terrestrial environments, but are underrepresented in thermal and environmental physiology datasets. As ectotherms, the activity of terrestrial arachnids is bounded by the critical thermal maximum (CT_{max}) and critical thermal minimum (CT_{min}). In Arctic and temperate climates, arachnids survive sub-freezing temperatures by either remaining unfrozen (freeze avoidant) or tolerating internal ice formation (freeze tolerant). In many arthropods, the thermal limits, and even cold tolerance strategy, are plastic. Here, we explore the thermal biology of a range of arachnids exposed to extreme conditions. We report that: The CT_{min} (mean= -3.6°C) and freezing temperature (supercooling point, SCP; mean= -6.9°C) are higher in the Beringian pseudoscorpion *Wyochernes asiaticus* (Yukon Territory) as compared to other small, high latitude ectotherms, as determined by previous studies. Whereas, the thermal limits (SCP and CT_{max}) of Arctic wolf spiders (*Pardosa* spp., Yukon Territory and Greenland; mean SCP= -5.4 to -8.0°C; mean CT_{max}=42.3 to 46.9°C) are also comparable to lower latitude ectotherms. These lower thermal limits are insufficient to allow arachnids to survive Arctic winters, therefore we tested for plasticity in the thermal limits. SCP and CT_{max} will change with acclimation in some *Pardosa* spp.; however, acclimation to low temperatures did not confer better low-temperature tolerance. Lastly, the temperate red velvet mite *Allothrombium* sp. is freeze-tolerant during winter. Thus, temperate and polar arachnids employ the full range of arthropod cold tolerance strategies.

P1-160 APREA, C/J*; MCALISTER, J/S; College of the Holy Cross; *cjapre18@g.holycross.edu*

Discerning developmental windows of larval feeding structure plasticity

As sea urchin larvae develop and grow post-fertilization, they produce a series of ciliated, skeleton supported "arms" that are used for feeding and swimming. Research has demonstrated that the size of these food-collecting structures trades off with the size of the primary food processing structure, the larval stomach. The magnitude and variability of the food treatment can also affect the magnitude of expression of these structures. Most studies of this phenomenon rear larvae in a single food treatment for the duration of the larval period, a condition which larvae are unlikely to experience in nature. As such, we understand little of how dynamic larval growth can be in response to changing food environments. We are conducting our experiments using larvae of the common sea urchin, *Lytechinus variegatus*, and will report how absolute and relative arm lengths, body lengths, and stomach volumes vary with respect to fluctuating food conditions. Preliminary observations made during data collection and analysis suggest that larvae fed high food initially and then switched to low food respond by lengthening their arms. We aim to discern the patterns of expression associated with the magnitude and plasticity of feeding and food-processing structures among larvae that are switched at specific time intervals from low to high food conditions and vice-versa. Our experiments will shed light on the existence and duration of distinct developmental windows for the expression of plasticity in this system.

P1-118 AQUIT, S*; SUZUKI, Y; Wellesley College; *saquit@wellesley.edu*

The molecular basis of a heat shock inducible color change in the tobacco hornworm, Manduca sexta

The phenomenon of phenotypic plasticity, common in insects, occurs when one genotype can generate different phenotypes in response to environmental changes. Genetic accommodation occurs when these environmentally induced phenotypes are selected on over multiple generations and lose their dependence on or become hypersensitive to the initial environmental cues. While the process of genetic accommodation has been demonstrated through artificial selection experiments, the genetic basis underlying this process remains unclear. Previous studies have shown that polyphenisms might evolve through genetic accommodation. In this project, a normally black mutant *M. sexta* strain was subjected to heatshock and the resulting epidermal color change was observed. A polyphenic strain and a monophenic strain were evolved through selection for either green or black epidermal color under heat-shock conditions.The expression of hormonal biosynthesis and response genes, specifically in the ecdysteroid and juvenile hormone (JH) signaling pathways, were analyzed in heat shocked and non-heat shocked selected animals and compared to the effects of heat shock on unselected control animals. Our initial findings suggest that JH signaling played a critical role from the onset of selection and mediated the heat-shock response. These studies will begin to help us better understand the process of genetic accommodation at the molecular level and ultimately allow us to determine whether genetic accommodation occurs in nature.

P3-49 ARCHER, JT*; DAVIS, JE; Radford University ; *jarcher4@radford.edu*

The Effects of Vespa Amino Acid Mixture on Mitochondrial Defect Induced Locomotion Disorders in Drosophila melanogaster

Vespa Amino Acid Mixture or VAAM is a chemical compound found naturally in Japanese giant hornet larva (*Vespa mandarinia japonica*). VAAM, via tropholactic delivery from larva to adult, assists hornets in flying great distances to bring back resources to the colony. Although studies in our laboratory have shown that VAAM acts as a mitochondrial accelerator, little is still known about how it works inside the mitochondria. The purpose of this study is to expand our understanding of how VAAM works to modulate mitochondrial function and the subsequent influences of this on development and behavior. Two mutant strains of fruit flies (*Drosophila melanogaster*) that have known mutations impacting ATPase subunit 6 and Cytochrome c oxidase were exposed to VAAM. Longitudinal measures of mortality and endurance were conducted to determine whether or not VAAM has any effect on that particular part of the mitochondria. Here we discuss our findings and how they relate both to VAAM and to functioning of the electron transport chain as modulated by these particular mutations.

P2-82 ARIAS, L*; ATWOOD, A; DUDLEY, E; DAVIS, JE; Radford University; *larias3@radford.edu*

Modulation of vegetative growth by frass derivatives from Madagascar Hissing Cockroaches (Gromphadorhina portentosa)

Recent research in the Radford Ecophysiology lab has shown that frass from Madagascar hissing cockroaches (*Gromphadorhina portentosa*) has similar chemical characteristics to organic fertilizers. Specifically, infrared spectroscopy demonstrated that frass contains functional groups similar to those found in both synthetic fertilizers and cow manure. In the current project, we set out to determine if frass from Madagascar hissing cockroaches modulated growth of *Raphanus raphanistrum*, *Solanum lycopersicum* and *Lactuca sativa* under a variety of treatment conditions and dilutions. Growth trials of three-week increments were conducted under controlled conditions. Resulting growth was analyzed based on both overall plant size and relative growth of subcomponents (roots, stem, leaves) across and within species and concentrations gradients. Results suggest that in moderate to high concentrations, frass was fatal to plants, causing an inhibition of growth, however, this inhibition varied across plant species. In contrast, low concentrations, below or comparable to that used in commercial fertilizer produced a significant increase in plant growth across multiple metrics. Here, we discuss these results, as well their implications both for natural plant-insect interactions and in agriculture.

95-3 ARMSTRONG, EJ*; HILL, RW; ROA, JN; TRESGUERRES, M; STILLMAN, JH; INABA, K; MORITA, M; Univ. of California, Berkeley, Mich. State Univ., Scripps Inst. Oceanography, UCSD, Scripps Inst. Oceanography, UCSD, Univ. of Tsukuba, Shimoda, Univ. of the Ryukyus; *armstrong@berkeley.edu*

Acid Secretion in Giant Clams Facilitates Burrowing Into Coral Reefs

Giant clams (genus *Tridacna*) are the largest living bivalves and are ecologically important members of Indo-Pacific reefs. Several species exhibit the remarkable ability to bore fully into coral skeletons and are major agents in reef bioerosion. The mechanisms facilitating boring in these species however, have remained unresolved. Although acid secretion has been implicated, early failures to detect acidification signals led to hypotheses involving purely mechanical or non-acidic chemical mechanisms such as shell rasping and calcium-chelation. Here, we definitively addressed the question of acid secretion in the boring giant clam, *T. crocea*. Using novel 2D-imaging optode technology and manipulating clams so that they press their pedal mantle against pH-sensitive foils, we show this organ is able to acidify the contact surface to at least 3 pH units below seawater. Further, we demonstrate that vacuolar-type H^+-ATPase (VHA), a H^+-transporter implicated in acid secretion in other epithelia, is highly abundant within *T. crocea* pedal mantle and localized in the apical membrane of cells in contact with coral skeleton. Similar localization patterns of VHA have been demonstrated in human osteoclasts and in *Osedax* worms suggesting that active H^+-secretion by VHA may be a common mechanism for dissolving carbonate substrates, an exciting example of convergent evolution. Our identification of VHA in giant clams and demonstration that bored surfaces are chemically acidified rather than mechanically rasped solves a decades old mystery and sets the stage for a greatly improved understanding of both the cause and fate of eroded reef carbonates.

64-3 ARMSTRONG, AF*; GROSBERG, RK; Univ. of California, Davis; *frarmstrong@ucdavis.edu*

The beginning of the end: gene expression changes in the evolution of non-feeding larvae

The evolution of feeding and non-feeding larval types has occurred repeatedly in both terrestrial and marine phyla, however we lack a detailed understanding of how such shifts occur. We analyzed development and gene expression in two seabiscuit species with alternate larval types and their hybrid offspring in order to investigate the evolution of larval type. Clypeaster subdepressus develops via a typical, obligately feeding, pluteus, which must feed in order to reach metamorphosis. However, Clypeaster rosaceus larvae develop via a rare intermediate mode—facultative planktotrophy—where they can feed but do not need to feed during their larval period. This intermediate larval type is presumed to be the one of the first steps in the transition to non-feeding development. In our crosses between these species, both reciprocal hybrids developed via the feeding mode of their maternal species rather than displaying a unique phenotype. In order to investigate the genetic basis of the developmental patterns we observed, we assembled developmental transcriptomes for both species using the program Trinity. We then analyzed gene expression patterns throughout development in both parental species and each reciprocal hybrid cross in order to identify gene expression patterns associated with each life history. We found differences in the timing and developmental stage at which genes were expressed in each cross. Our results suggest that accelerated gene expression may be an important initial step in the evolution of non-feeding larval development.

P3-73 ASHFORD, MA*; BOWDEN, RM; PALACKDHARRY, SM; VOGEL, LA; Illinois State University, University of Cincinnati ; *maashfo@ilstu.edu*

Formation of ILF-like Structures in Hatchling T. scripta

Gut-associated lymphoid tissue (GALT) is essential for protection against ingested pathogens (many consumed in food) and maintenance of normal gut microbiota. While much is known about the mammalian gut and lymphoid tissues associated with it, gut immunity is much less understood in reptilian species. Of particular interest are small structures called isolated lymphoid follicles (ILF), consisting primarily of B cells and found throughout the small intestine. In mammals, the formation of the ILF is not developmentally driven like other lymphoid tissues such as Peyer's Patches, but is rather dynamic and induced through antigenic stimulation and diet. We have now identified ILF-like structures in the red-eared slider (Trachemys scripta) turtle. Our preliminary studies have shown high variation in the presence and location of these structures in hatchling animals by use of a specific primary antibody to turtle Ig (HL-673). Furthermore, in the turtle, these ILF-like tissues have shown possible variation in presence in response to when the clutch was laid (i.e. early nesting season or late nesting season). In order to determine if the observed ILF-like structures are inducible, similar to those in mammals, we will introduce enteric Salmonella through oral gavage to hatchling turtles and allow colonization. Gut tissue will then be analyzed through whole mount immunohistochemistry for the distribution of B cell staining. The overall effect of season will also be tested. These studies will provide novel information about gut immunity in non-mammalian vertebrates.

1-5 ASSIS, VR*; GARDNER, S; GOMES, FR; MENDONCA, MT; Univ. of Sao Paulo, Sao Paulo, Auburn University, Auburn; *v.regina.a@gmail.com*

Invasive Cane Toads Response to a Challenge with Sheep Red Blood Cells (SRBC): an Energetic and Immune Approach

Invasive species are a major driver of biodiversity loss. Some hypotheses suggest successful invaders would demonstrate different stress and immune response profiles than native species. The higher dispersal rate common in invasive species are associated with elevated energetic demands and glucocorticoids levels (GCs). Additionally, it is hypothesized that invasive species should utilize one type of immune response (innate or adaptive) over the other based on energetic cost of the response, potentially reducing pathogen load. We explored the relationship among GC, immune responsiveness, and energetic cost in cane toads (Rhinella marina), an invasive species in Florida. Toads (N=14) were acclimated to captivity for 3 weeks at which time we measured their metabolic rate (MR) and took a blood sample to determine their bacterial killing ability (BKA, an innate immune response), corticosterone levels (CORT) and antibody titers (IGG). Toads were then injected with 20% SRBC or saline solution. One-week post injection, toads' MR was again measured. They were re-bled and re-challenged with 20% SRBC or saline injections. We predicted SRBC challenged toads would exhibit higher MR, CORT and IGG, while showing lower BKA. We found a significant increase in IGG in SRBC vs. saline injected toads 7 days after injection ($F_{1,11}=8.513$, $p=0.014$). The second SRBC challenge did not significantly increase IGG over levels observed after the first challenge in SRBC toads ($p=1.000$). There was no difference between saline vs. SRBC in MR ($F_{1,12}=1.149$, $p=0.305$), but MR increased in SRBC challenged toads after 7 days compared to before injection ($p=0.028$). There were no significant differences in CORT ($F_{1,11}=0.031$, $p=0.863$) or BKA ($F_{1,11}=1.269$, $p=0.284$) between SRBC and saline controls.

139-7 ASSIS, BA*; AVERY, JD; LANGKILDE, TL; The Pennsylvania State University; *bmd5458@psu.edu*

Costs Associated with Male-typical Traits on Female Lizards: Reduced Offspring Survival and Growth

Male eastern fence lizards display conspicuous ventral blue badges with important functions in courtship and agonistic interactions. These same badges can be found on females, albeit never as dramatic as seen in males, and with significant variability in intensity. Previous research has shown that females bearing blue badges are disfavored as mates, but have performance advantages that could counterbalance their reproductive costs. Currently, we are interested in the relationship between the degree of maternal ornamentation and the fitness of offspring. We first determined a color metric that was insensitive to temperature (which affects badge coloration in this species). Using this metric, we found that offspring of females bearing more saturated badges exhibited reduced mass gain since hatching and were less likely to survive to maturity. These results add to the series of documented evolutionary costs faced by females bearing traits that are typical of males, highlighting the importance of future investigation on potential benefits associated with this trait. The mechanisms behind badge development and associated costs and benefits are the subject of our future work, where we will quantify levels of different sex hormones in these females and throughout different life stages of their offspring. With this, we hope to further study the potential connection between physiology, color, and other fitness-relevant traits such as immune response, performance and mating success, factors that could be responsible for the maintenance of male-typical ornamentation in females.

P2-167 ASTLEY, H.C.; University of Akron; *hastley@uakron.edu*

Traversing Tight Tunnels - Implementing an Adaptive Concertina Gait in a Biomimetic Snake Robot

Snakes are extraordinarily capable of moving through cluttered habitats, tight spaces, and around obstacles, and consequently snake robots are a popular design for negotiating such situations. The remarkable locomotor performance of snakes in these environments has been attributed to both their elongate, serially metameric body plan and to their diversity of locomotor modes, each of which are used in different contexts. Concertina locomotion is the mode used by snakes to negotiate narrow spaces such as tunnels or bare branches, in which the snake forms an anterior anchor region while pulling the posterior body forwards, then forms a posterior anchor region while pushing the anterior body forwards. Although slow and energetically expensive, concertina locomotion is highly versatile, requiring only a surface to generate anchoring forces against, and is used as a final option when other modes are infeasible. In spite of the utility of this locomotor mode, concertina locomotion has rarely been implemented in snake robots, and only with a fixed, pre-specified tunnel diameter. In this paper, I use motion capture technology to conduct detailed examination of the anchor formation process in snakes using concertina locomotion in tunnels of two widths. These data were analyzed and used to design and implement an algorithm for a dynamic concertina locomotor mode in a snake robot, in which contact with the tunnel walls is automatically detected and used to modulate the waveform. This algorithm was applied to a "generalist" snake robot, allowing it to successfully perform concertina locomotion at a range of tunnel diameters by dynamically adapting its posture to the tunnel width based only on local feedback, with no prior information on tunnel width. This algorithm can be useful for snake robots when moving through tunnels, while limiting the need for either user input or complex sensor systems to characterize geometry.

P1-181 ATWOOD, A/C*; O'BRIEN, S; MONCEAUX, C/J; Radford University; *aatwood4@radford.edu*

Optimization of EDC Detection in Aquatic Environments: LCMS Detection & Quantification of Trenbolone

Endocrine disrupting chemicals (EDCs) can directly interfere with an organism's endocrine system by mimicking naturally occurring hormones, thus eliciting a response similar to that of natural hormones. However, the timing or degree of this response is abnormal. For this reason, many EDCs are considered environmental pollutants. One compound that has been of particular concern as of late is trenbolone acetate, a synthetically produced anabolic-androgenic steroid that is used as a growth promotor in the cattle industry and has a high affinity for androgen and progestin receptors *in vivo* (Bauer, et. al., 2000). Because the half-life of trenbolone is upwards of eight months, there is an immense potential for aquatic organisms to be exposed to trenbolone via agricultural runoff (Schiffer et. al., 2001). Therefore, exploring the levels of trenbolone in aquatic environments is exceedingly important to the health of our environment, as exposure to high levels of androgens can cause masculinization and behavioral changes in individuals. The morphological, developmental, and behavioral changes that trenbolone elicits are well documented (Ankley et. al., 2009 & Orn et. al. 2006). To date, several studies have demonstrated that trenbolone is, in fact, present in water sources due to runoff (Durhan et. al., 2006 & Schiffer et. al. 2001). However, the relationship between aquatic trenbolone levels and the amount of trenbolone present in the tissues of aquatic animals is far less understood. With this project, we optimized a HPLC and LCMS procedure to identify and quantify trenbolone levels in laboratory and field samples in order to better understand the temporal and spatial changes in trenbolone exposure within these paradigms.

S9-7 AUSTAD, Steven N.; University of Alabama at Birmingham; *austad@uab.edu*

The Comparative Biology of Mitochondrial Function and the Rate of Aging

In recent years many methods have been developed by biogerontologists to extend life and improve health in laboratory animals. These methods include modulating food composition and feeding rate, inactivating genes, and dietary supplementation with pharmacological agents. Also, numerous species have been identified that in the natural world appear to have exceptional resistance to the damaging processes of aging. Confusingly given its central role in energetics, ROS generation, and apoptosis, some of life extending treatments and exceptionally long-lived species appear to have reduced mitochondrial activity, others have enhanced mitochondrial activity. This talk will take a comparative approach to these seemingly contradictory findings to try to resolve them into an evolutionarily coherent pattern.

19-3 AUSTIN, SH*; MACMANES, M; LANG, A; CALISI, RM; UC Davis, Univ. of New Hampshire; *shaustin@ucdavis.edu*

The transcriptomics of parenting: uncovering sex-biased gene activity in an avian biparental system

Hormones play a key role in initiating and maintaining parental behaviors, but we know little about underlying genomic activity driving these processes. In the rock dove (*Columba livia*), both sexes engage in all stages of contact-incubation and chick-rearing. This begs the question, are the underlying mechanisms facilitating these parental care behaviors the same in males and females? Using a highly replicated RNAseq experiment, we investigated how gene expression in three important tissues critical for reproductive behavior, the hypothalamus in the brain, the pituitary gland, and the gonads (testes and ovaries), changes in both sexes over the course of the parental care. We found parental care stage-specific and tissue-specific sex-biased gene expression in substrates commonly investigated when studying parental care and reproduction. In addition, we uncovered new genes to target for further investigations. Our results unveil the dynamic and sex-biased nature of the genome over the course of parental care. We will discuss how these data are now providing a foundation for our ongoing hypothesis-driven studies of mechanisms regulating parental care.

66-5 AUSTIN, M*; ITURRALDE, P; WEST, K; DUNLAP, A; University of Missouri, St. Louis; *mdaf2b@mail.umsl.edu*

The Best Laid Plans: Testing the Generality of Experimentally Evolved Oviposition Preference

Innate cognitive and sensory biases can heavily influence the decisions an animal makes in its environment. In many species, sensory biases have been shown to influence disparate components of an animal's life history (e.g specific color bias for both feeding and mate selection). Although it is often assumed that these observed overlaps in behavioral biases have evolved due to pleiotropic effects, our incomplete knowledge of the exact evolutionary pressures that shaped a given animal's behavioral biases makes it impossible to verify this assertion in a natural setting. Using experimental evolution for 140 generations, we successfully evolved differential oviposition biases for pineapple and orange flavored substrates in replicate populations of the fruit fly, Drosophila melanogaster. We subjected adults and larvae from these populations to a series of assays to determine if evolved oviposition bias influenced decision making behavior when feeding on, flying towards, or standing on orange and pineapple substrates. We did not find a positive correlation between any of the newly assayed behaviors and a population's originally evolved oviposition bias. To better understand our findings, we used Real-Time PCR to analyze tissue-specific differential expression of several genes implicated in oviposition, decision making and gustatory perception. Our study, which to the best of our knowledge represents the first such investigation into an experimentally evolved sensory bias, suggests that innate biases can evolve in an extremely specific manner that does not affect other measured aspects of behavior and decision making.

P1-153 AWALI, S*; MARDINI, MR; KAGEY, JD; BELANGER, RM; University of Detroit Mercy; *awalisa@udmercy.edu*

Atrazine exposure causes DNA damage and changes in cytochrome P450 expression in the hepatopancreas of crayfish (Orconectes virilis)

Atrazine is a heavily applied herbicide in the United States to control the growth of broad-leaf weeds. After application, atrazine enters local waterways through seepage or run-off. Atrazine concentrations in the environment have been recorded above 300 ppb and these high concentrations are known to persist for more than 21 days. Crayfish are an ideal bioindicator of environmental contamination because they display quantifiable responses to sublethal concentrations of contaminants. In order to examine the effects of atrazine on non-target aquatic organisms, we exposed crayfish to environmentally-relevant (80 and 300 ppb) and control concentrations (0 negative control) and 1000 ppb ATR (positive control) for 15 days. Following exposure, we removed the hepatopancreas (digestive gland) and examined DNA damage using comet assays and cytochrome P450 activity levels using an enzyme-linked immunosorbent assay. We found that exposure to atrazine caused increases in the number of cells that have comets, as well as an increase in the size of the comet tails. Further, significant induction of cytochrome P450 occurred as atrazine concentration increased. Overall, we found that environmentally-relevant atrazine exposure caused cellular-level changes in hepatopancreas of crayfish. If health is interrupted in crayfish species, the physiology of other species (e.g. fish) may also be declining due to exposure to these herbicides. Moreover, research on DNA damage and cytochrome P450 activity will have applications for humans, especially for determination of safe levels of atrazine in drinking water. This work significantly increases our knowledge about the non-target effects of ecologically-relevant concentrations of atrazine.

P2-133 AYYAGARI, S*; CABALLERO, S; HINES, E; COHEN, CS; San Francisco State University, Universidade de los Andes; *sbayyaga@gmail.com*

Assessing Genetic Diversity in the Irrawaddy Dolphin (Orcaella brevirostris)

Southeast-Asian Irrawaddy dolphins (*Orcaella brevirostris*) are highly susceptible to anthropogenic effects that reduce effective population size and genetic diversity. Coastal populations are currently listed as "Vulnerable" on IUCN's Red List, while some riverine populations are listed as "Critically Endangered". Though conservation efforts in developing countries have improved with abundance, habitat, and range data, additional genetic information will best inform management. Comparison of variation at adaptive immune system loci (Major Histocompatibility Complex, MHC) and neutral loci allows us to assess the severity of population bottlenecks. Irrawaddy dolphins (n=23) from the Gulf of Thailand were sequenced at the MHCIIDQB locus and just one allele was found in this population. In comparison, one allele was also found in Mekong Irrawaddy dolphins (n=37). This severe bottleneck in coastal populations is concerning, as riverine populations of *O. brevirostris* are hypothesized to have even lower MHC diversity due to intense anthropogenic pressures in a more confined habitat. Even in comparison to the low MHC diversity in endangered dolphin populations (e.g. *Sousa chinensis* and *Phocoena sinus*) residing in anthropogenically impacted habitats, no variation in a usually highly polymorphic locus is very uncommon and suggests low potential for *O. brevirostris* populations to adapt to novel pathogens. Preserving the diversity of essential functional loci in *O. brevirostris* should therefore be a top priority for conservation managers.

P3-113 BAAS-THOMAS, N*; STEELE, T; ZORNIK, E; Reed College; *thesteel@reed.edu*

Investigating the Plasticity of Sexually Differentiated Vocalizations in Adult Xenopus laevis

The study of sexually differentiated behaviors has focused on the effects of gonadal steroids during development, but the degree to which behaviors retain hormone-dependent plasticity is variable across behaviors and species. African clawed frogs (*Xenopus laevis*) produce rhythmic, sexually differentiated mating calls driven by a serotonin-dependent hindbrain central pattern generator (CPG). Male courtship vocalizations require circulating androgens. Sexually mature female *Xenopus* develop male-typical calling when treated with androgens. We wish to determine the hormonal and neuronal mechanisms that underlie this behavioral plasticity in *Xenopus*. Whole-cell recordings in the vocal CPG identified premotor neurons in T treated female brains with activity closely resembling that of "Fast Trill Neurons". These cells, previously identified in male brains, spike in patterns closely correlated with masculinized vocal behavior. This finding supports our hypothesis that Fast Trill Neurons, and their female precursors, are essential targets of androgen-mediated behavioral changes. Masculinization of the vocal CPG begins rapidly in response to testosterone; however, testosterone is the primary circulating ovarian steroid. We explored whether the effects of testosterone treatment differed in ovariectomized versus non-ovariectomized females. We found that call rates were similar at all time points across treatments, independent of serum testosterone concentration. Future work is required to determine if masculinization occurs in response to sustained elevation of T, or in response to supraphysiological concentrations of T. Regardless of the outcome, *Xenopus* vocal behavior is an excellent system for assessing the mechanisms that underlie steroid-dependent plasticity in adult vertebrates.

P1-119 BABONIS, LS*; DEBIASSE, MB; FRANCIS, WH; CHRISTIANSON, LM; HADDOCK, SHD; MARTINDALE, MQ; RYAN, JF; University of Florida/Whitney Lab, Monterey Bay Aquarium Research Institute , Monterey Bay Aquarium Research Institute, Monterey Bay Aquarium Research Institute ; *babonis@whitney.ufl.edu*

Not your mama's tentacle: Molecular characterization of ctenophore colloblasts

Colloblasts are a novel cell type found only in the tentacles of ctenophores (comb jellies). Upon contact, colloblasts secrete a sticky adhesive facilitating prey capture. These unusual cells were present in the last common ancestor of ctenophores but were lost in the stem of the clade containing *Haeckelia* and *Beroe*, the latter of which has lost tentacles altogether. Despite their important role in the ecology of ctenophores, little is known about the origin of colloblasts or the nature of the substance they secrete. We surveyed the transcriptomes of 36 species of ctenophores, including three from the genus *Beroe* and two from the genus *Haeckelia*, to identify genes that may have been lost concomitant with the loss of colloblasts and/or tentacles. Using a developmental time course of single-embryo RNA-Seq data from *Mnemiopsis leidyi*, we show that the expression profiles of candidate colloblast genes are distinct from other genes expressed during embryogenesis, exhibiting higher expression specifically during tentacle development. Functional annotation of these candidates suggests that proteins associated with post-translational modification and ion transport are abundant in colloblasts but no proteins with clear orthology to adhesive proteins from other species (e.g., barnacles) were identified. Additionally, over 30% of the colloblast-specific genes identified from the phylogenomic survey lacked known functional domains, suggesting they encode novel (potentially ctenophore-specific) proteins. Our analyses provide an intriguing first glimpse into the genetic makeup of ctenophore tentacles and their associated novel prey-capturing adhesive cells.

48-7 BABONIS, LS*; MARTINDALE, MQ; University of Florida/Whitney Lab; *babonis@whitney.ufl.edu*
Early specification of ectodermal cells in the pharynx and mesenteries of the sea anemone Nematostella vectensis
The gastrovascular cavity (GVC) is the primary site of digestion and nutrient absorption in cnidarians (hydroids, jellies, etc) and is lined by a layer of tissue derived from the embryonic endoderm. In most cnidarians, the GVC is populated by numerous enzymatic gland cells. Curiously, among anthozoans (corals, sea anemones, etc.), the GVC is lined by endoderm but the gland cells are restricted to the ectodermal layer of the pharynx and mesenteries. To better understand the relationship between cell identity and embryonic tissue identity, we characterized the development and cell biology of tissues associated with the GVC in the model sea anemone, *Nematostella vectensis*. Using light and electron microscopy, we describe the presence of several distinct gland cell types in the ectodermal portion of the pharynx and mesenteries in adult anemones. We further characterize the molecular identity of the mesenteries using RNA-Seq and show that the top-expressed genes from this tissue share homology with vertebrate digestive enzymes including chymotrypsins, phospholipase A2, and chitinase. Using *in situ* hybridization, we demonstrate the expression of several of these genes in ectodermal cells of the presumptive pharynx/mesenteries just after gastrulation, suggesting that enzyme-secreting cells are among the first internal cells to be specified in *N. vectensis*. While many of the upregulated genes from the mesenteries of *N. vectensis* are also specific to the gland cell lineage in *Hydra*, in the former these cells are derived from ectoderm and in the latter from endoderm. These data suggest that mis-expression of an endodermal cell lineage in an ectodermal tissue may have shaped the evolution of digestive system in cnidarians.

P3-138 BACKMAN, I.R.*; ABREU, D; CHOI, F.N.; HELMUTH, B.S.; Saint Michael's College, Northeastern University; *ibackman@mail.smcvt.edu*
The effect of repeated exposure and local adaptation on lethal temperatures of Littorina littorrea from the Gulf of Maine
Global climate change is causing an increase in the number of extreme weather events such as heat waves, which can have far greater effects on organisms and ecosystems than simple changes in mean conditions. Physiological vulnerability to extreme events also varies significantly among species, populations and even conspecific individuals. We studied the effects of heat waves of varying intensity and duration on the intertidal gastropod *Littorina littorea*, an abundant and ecologically important species in the North Atlantic. We measured the thermal LT50 of *L. littorea* from six populations in the Gulf of Maine spanning 2 degrees of latitude. In our experiment, we 1) looked at changes in mortality through repeated 6h exposures (1, 2 or 3 days) to aerial temperatures ranging from 35°C to 43°C and 2) examined how responses varied among the six populations. We hypothesized that *L. littorea* from different locations will vary in their thermal tolerances due to local adaptation, but that these differences may only be detectable after repeated exposures. We also hypothesized that multiple exposures to high temperatures would reduce thermal tolerance. Our results demonstrated a significant decrease in LT50 from 1st day to 3rd day exposures across all sites. However, although there was slight variation of LT50 across sites, we found no significant difference among the three sites. Exploring inter-population variability in vulnerability to repeated exposures is critical if we are to understand how climate change will affect distribution patterns in nature, yet experiments such as these have not been conducted for most intertidal species.

73-1 BADGER, M*; CHANG, U; COMBES, S; University of California, Davis; *badger@berkeley.edu*
Down in the mouth: Consequences of mandible-loading for flight stability in blue orchard bees (Osmia lignaria)
The ability to carry loads in flight is critical for survival and reproduction in many flying insects. Although some insects carry loads near or directly below the center of mass, mud daubers, yellowjackets, mason bees, and many other insects carry food or nesting materials in the mandibles, which noticeably shifts the center of mass forward. Such fore-aft shifts in the center of mass are expected to have important consequences for flight control, but the kinematic changes required to maintain controlled flight and the resulting effects on maneuverability and stability have not yet been explored. To address these questions, we filmed blue orchard bees (*Osmia lignaria*) at 5000 fps as they transported mud loads in their mandibles during nest construction. We also filmed bees as they carried artificial loads mounted directly above the center of mass and on the ends of long booms, which shifted the center of mass even farther forward than mandible loading. Using reconstructed body and wing trajectories we tested the hypothesis that responses to imbalanced loads would be similar those exhibited during active pitching maneuvers in other insects. We also tested the hypothesis that imbalanced loads would reduce flight performance in turbulent flow in a wind tunnel to a greater degree than similar loads carried directly above the center of mass. If bees control body pitch using the same strategies they use to compensate for imbalanced loads, such loads may limit control authority and introduce unique challenges for these insects in inclement weather. Principles extracted from our observations of maneuvering flight while unevenly loaded may also inform design efforts for small aerial vehicles carrying off-center loads attached to arms, grabbers, or other manipulators.

51-3 BAGGE, LE*; KIER, WM; JOHNSEN, S; Duke, Univ. of North Carolina at Chapel Hill; *laura.elizabeth.bagge@gmail.com*
The ultrastructure of transparent shrimp
Transparency allows animals to match any background, but it is unknown how complex tissues are modified to achieve whole-body transparency. We used transmission electron microscopy to investigate how shrimp muscle is modified to minimize light scattering. We investigated muscle ultrastructure in a transparent species, *Ancylomenes pedersoni*, in comparison to a similarly sized opaque species, *Lysmata wurdemanni*, and found that the myofibrils of the transparent species were twice the diameter of those of the opaque species (2.2μm vs.1.0μm mean). Over a given distance of muscle, light will pass through fewer myofibrils due to their larger diameter, and there will be fewer opportunities for light to be scattered at the interfaces between the high-index myofibrillar lattice and the surrounding lower-index sarcoplasmic reticulum (SR). A similar result was found in a distantly related vertebrate group - silurid catfish - with transparent catfish having larger myofibrils than opaque catfish (Johnsen and Kier, unpublished data previously reported at SICB). This suggests that multiple taxa have arrived at the same solution of minimizing scattering interfaces in muscle tissue. Additionally, because transparency is not always a static trait and can sometimes be disrupted after exercise or physiological stress, we compared the ultrastructure of muscle in transparent *A. pedersoni* with the ultrastructure of muscle in *A. pedersoni* that had temporarily turned opaque after exercise. We found that in the opacified tissue, the SR around myofibrils had an increased thickness of 360nm as compared to a normal thickness of less than 20nm. We modeled the light scattering across a range of SR thicknesses and possible refractive indices to show that this observed increase in SR thickness dramatically reduces transparency.

85-4 BAGHERI, H*; JAYANETTI, V; BURCH, HR; MARVI, H; Arizona State University; *hbagheri@asu.edu*

Basilisk Lizards Transition Strategies from Land to Water

Basilisk lizards are renowned for their aptitude to traverse virtually on and between any complex natural medium and diversified terrains: tree trunks, rocks, sand, mud, and water. They can also perform different locomotion gait patterns: walking on all four limbs, running on two hind legs, hopping, and even swimming under water, just to name a few. This makes them an ideal reptile to analyze their kinematics, locomotion, and morphology as they transition from one environmental setting to another. The study will evaluate distinct strategies and methodologies used by juvenile basilisks (*Basiliscus plumifrons* and *Basiliscus vittatus*) as they transition from land to water, and vice versa. A 6m by 0.5m long modular track has been designed and constructed to examine various environmental parameters, such as depth, length, and inclination of both water and granular media (i.e. sand, mud). Through a series of systematic animal studies, a better understanding can be obtained on how basilisk lizards adapt from terrestrial to aquatic locomotion. The research will lead to future efforts in designing and developing robotic systems with the ability to traverse on, through, and between terrestrial terrains and aquatic environments.

74-3 BAGHERI, H*; GENDT, AB; CUMMINGS, SD; SUBRAMANIAN, S; BERMAN, SM; PEET, MM; AUKES, DM; HE, X; FISHER, RE; MARVI, H; Arizona State University, BASIS Chandler, Arizona, University of Arizona; *hbagheri@asu.edu*

Octopus Sucker Adhesion and Suction Performance Under Various Environmental Conditions

The octopus holds great promise as a model for the design of soft robotics. Octopus arms are muscular hydrostats with infinite degrees of freedom, providing the ability to execute diverse modes of locomotion, including jetting, swimming, crawling, and walking. At the same time, the arms can also apply great force to perform a range of tasks such as fetching, grasping, and manipulating objects. Octopus suckers play a key role in executing many of these locomotor and anchoring tasks. Experimental evidence suggests that suckers can hold high adhesive forces on both wet and dry surfaces with various topographies. While prior research has been conducted on the muscular structure and some of the mechanical properties of octopus suckers, little to no effort has been put towards evaluating the effects of environmental conditions (i.e. temperature and salinity) on adhesion and suction. The suckers of two octopus species (*Octopus vulgaris* and *Octopus bimaculoides*) will be detached from the arms to examine their adhesive and suction properties. Temperature and salinity ranges of 15-22°C and 33-37%, respectively, will be used as the experimental parameters, as these correspond to conditions in the natural habitats of these two species. The findings of this study will be essential in the development of versatile attachment mechanisms for aquatic soft robotic systems.

34-1 BAI, B*; FOX, J; Hathaway Brown School, Case Western Reserve University; *bbai18@hb.edu*

Dissecting Fly Haltere Function during Flight and Walking

Insect nervous systems are capable of processing complex sensory information at remarkable speeds. Flies collect this information in part from halteres, a set of mechanosensory organs, which are crucial for flies to maintain flight equilibrium, but what sensory information each haltere provides during flight and other behaviors remains uncertain. To determine the role of individual halteres in flight behaviors, high-speed video was used to examine effects of removing one or both halteres in two different fly genera, *Sarcophaga* and *Calliphora*. Flies with only one haltere, when compared to intact and haltereless flies, displayed intermediate behavioral deficits in flight duration, flight trajectory, and landing success, but not a complete loss of stability. Haltereless *Sarcophaga* filmed over a two-week period after haltere removal had no recovery of flight stability. Additionally, *Sarcophaga* beat their halteres during walking, a trait not seen in all flies. Examination of various walking behaviors, such as stair climbing, vertical walking, and posture control during vibrational perturbations demonstrated that haltereless flies climb less and fall more often during vertical walking. Thus, subtle and specific deficits in single-haltere flight and haltereless walking suggest more complex sensory control in both behaviors.

67-7 BAIER, DB*; MORITZ, S; CARNEY, RM; GARRITY, B; Providence College, Brown University, University of South Florida, Boston University; *dbaier@providence.edu*

Finding the Invisible Joint: Developing a Joint Coordinate System for the Alligator (Alligator mississipiensis) Coracosternal Joint

X-ray Reconstruction of Moving Morphology (XROMM) can be used to recreate skeletal motion of living animals by animating 3-d computer-generated models of the bones. Kinematic measurements from these animations require clearly defined joint coordinate systems (JCS). In most cases, anatomical landmarks from proximal and distal bones on either side of the joint can be used to orient a JCS. However, the alligator sternum is cartilaginous and is invisible in X-ray views and CT scan-based models of intact animals. Thus, the proximal end of the coracoid, which articulates with sternum, appears to "float" on the ventral aspect of the thorax. This makes orienting the JCS consistently between different individuals challenging. Here, we explore a method for reconstructing the cartilaginous elements to place of the coracosternal JCS. The JCS is then used to measure coracosternal motion XROMM data from four alligators performing the high walk on a treadmill. Models of the cartilages of the sternum and scapulocoracoid are derived from CT scans of a reduced dissection preparation with only cartilages and bone intact. These polygonal mesh models are then scaled and aligned to each of the experimental animals based on the bony interclavicle which runs within the midline of the sternum. Results suggest that while patterns of movement between individuals are highly consistent, there are offsets in the magnitudes for some axes in some individuals. These offsets may true variation between individuals or could be associated with slight variations in the orientation of the interclavicle within the sternal cartilage. Ideally, the sternum should be reconstructed from the anatomy of each individual which would distinguish between these two possibilities.

116-1 BAILLEUL, A/M*; HOLLIDAY, C/M; University of Missouri; *bailleula@missouri.edu*

Retracing the evolution of the otic joint in birds and fossil theropods through histology: new insights on streptostyly

The otic joint is functionally important in many sauropsids, as it often allows movement during feeding, a condition known as streptostyly. This type of cranial kinesis is found in many birds, as shown by in vivo studies and skeletal manipulations. Many inferences of kinesis at this joint in fossil theropod dinosaurs have been made using morphological arguments, even though its structure-function relationships are still poorly understood in extant birds. To document the numerous changes that occurred in the morphology, composition and function of the otic joint during theropod evolution, we used microCT scanning and histology of five species of birds that display a range of kinetic behaviors: the emu (Casuariiformes), the mallard duck (Anseriformes), and three species of parrot (Psittaciformes). We also sampled two species of non-avian theropod dinosaur (Tyrannosaurus and Allosaurus) and outgroup taxa including the American alligator, Common snapping turtle and several species of lizard. All the avian species show similar histological characteristics including a synovial microstructure with secondary articular cartilage on the squamosal. We found these histological characters suggestive of avian-style streptostyly in the otic joints of Tyrannosaurus and Allosaurus. These results suggest avian-style otic joint microstructure, and possibly streptostylic movements evolved prior to the origin of birds. This study reveals the histological underpinnings of avian-style cranial kinesis, retraces the evolution of streptostyly in theropod dinosaurs, and illuminates the diversity of cranial joint structure and function in sauropsids and vertebrates.

S8-5 BAKER, Clare/VH; University of Cambridge; *cvhb1@cam.ac.uk*

The development and evolution of vertebrate lateral line electroreceptors

The vertebrate lateral line system is a useful model for investigating the embryonic and evolutionary diversification of sensory organs and cell types within the nervous system. In non-teleost vertebrates, including lampreys, this sensory system comprises neuromasts containing hair cells that detect local water movement, electrosensory organs containing electroreceptor cells that respond to low-frequency cathodal electric fields (used primarily for hunting), and the afferent neurons for both organ types, projecting to adjacent medullary nuclei. The electrosensory division was independently lost in the bony fish lineages leading to teleosts and to frogs (amniotes lost the entire lateral line system during the transition to life on land). Within the teleosts, ampullary organs that respond to low-frequency anodal stimuli evolved independently at least twice in different groups, likely via the diversification of neuromast hair cells; their afferent lateral line neurons project to novel medullary nuclei. Some lineages also independently evolved both electric organs and tuberous organs that detect high-frequency electric organ discharges. We are using a comparative RNA-seq approach to investigate electroreceptor development and evolution. In a non-teleost fish, the paddlefish *Polyodon spathula*, we have identified expression in developing electrosensory organs of transcription factor genes critical for hair cell development, and genes essential for glutamate release at hair cell ribbon synapses, suggesting close developmental, physiological and evolutionary links between non-teleost bony fish electroreceptors and hair cells. We have also identified candidates for the voltage-sensing L-type Ca_v channel and rectifying K_v channel predicted from skate (cartilaginous fish) electrosensory organ electrophysiology. Overall, our results illuminate electroreceptor development, physiology and evolution.

122-6 BALABAN, JP*; AZIZI, E; Univ. of California, Irvine; *jbalaban@uci.edu*

Elastic energy storage broadens the thermal performance range of accelerating lizards

Many ectotherms exhibit a thermal plateau, over which whole animal performance is largely constant. One example is the western fence lizard, *Sceloporus occidentalis*, which maintains nearly constant running performance between 25° and 40° C. This performance plateau is apparent despite changes in muscle kinetics that would predict a performance decrease at low temperatures. Here, we test the hypothesis that fence lizards can use stored elastic energy to enhance muscle power and minimize the deleterious effects of low temperature on locomotor performance. We use 3D kinematics of lizard accelerations along with ground reaction force data collected from a six-axis force transducer under the left hind foot of the lizards to run an inverse dynamics analysis. We then use the mass of the limb extensors and their insertions to estimate muscle power during acceleration. From our preliminary data, we find that at 35° C, lizards may have just enough muscle to power the fastest accelerations we measured. However, at 25° C, we find that the muscle power needed to elicit the fastest accelerations is higher than the lizards can produce. We also find unexpected similarities in the ground reaction forces, timing of movement, and kinematics of lizards accelerating at 25° and 35° C. We believe these similarities provide additional evidence for elastic energy storage and power amplification during acceleration in lizards. These results add to the growing body of evidence that suggests elastic mechanisms allow ectothermic organisms to maintain performance across a broad thermal plateau.

41-5 BALDAN, D*; HINDE, C. A.; LESSELLS, C.M.; Department of Animal Ecology, Netherlands Institute of Ecology (NIOO-KNAW), P.O. Box 50, 6700 AB Wageningen, The Netherlands, Behavioural Ecology Group, Life Sciences, University of Wageningen, P.O. Box 338, 6700 AH, Wageningen, The Netherlands; *D.Baldan@nioo.knaw.nl*

Foraging coordination while feeding young: behavioural mechanisms underlying negotiation over offspring care

The amount of parental care provided to offspring is affected by sexual conflict and the negotiation rules that parents adopt. Recently, a 'turn-taking' provisioning rule by the parents has been predicted to increase parental care, and several empirical studies in birds indicate that parents do indeed alternate their nest-visits more than expected by chance. However, little is known as to whether parents actively take turns of feed and how they monitor the provisioning activity of the mate. We proposed two mechanisms by which parents monitor and respond to each other: coordination of foraging trips and monitoring at the nest (e.g. by waiting at the nest for the partner). We combined video recordings at the nests with Encounternet, a new automated radio-tracking technology, to remotely monitor provisioning activity of wild great tit (*Parus major*) pairs during chick rearing. We explored i) whether parents forage in spatial proximity or monitor each other at the nest, and ii) how these two behaviours relate to the pattern of the nest visits. This study links animal movement analysis to visit patterns at the nest and highlights the importance of studying the behavioural mechanisms underlying negotiation rules to better understand the evolution and maintenance of bi-parental care.

139-4 BALIGA, VB*; MEHTA, RS; Univ. of British Columbia, Univ. of California, Santa Cruz; *vbaliga@zoology.ubc.ca*

The interplay between life history patterns and phenotypic convergence in cleaner wrasses

Phenotypic convergence is a macroevolutionary pattern that need not be consistent across life history stages. Ontogenetic transitions in dietary specialization clearly illustrate the dynamics of ecological selection as organisms grow. Few studies have documented how the extent of phenotypic convergence among taxa that share a similar ecological niche may vary ontogenetically. Because ontogenetic processes have been shown to evolve, phylogenetic comparative methods can be useful in examining how scaling patterns relate to ecology. Cleaning, a behavior in which taxa consume ectoparasites off clientele, is well-represented among wrasses (Labridae). Nearly three-fourths of labrids that clean do so predominately as juveniles, transitioning away as adults. We examine the scaling patterns of 33 labrid species to understand how life history patterns of cleaning relate to ontogenetic patterns of phenotypic convergence. We find that as juveniles, cleaners exhibit convergence in body and cranial traits that enhance ectoparasitivory. We then find that taxa that transition away from cleaning exhibit ontogenetic trajectories that are distinct from those of other wrasses. Obligate and facultative species that continue to clean over ontogeny, however, maintain characteristics that are conducive to cleaning. Collectively, we find that life history patterns of cleaning behavior are concordant with ontogenetic patterns in phenotype in the Labridae.

93-3 BALK, MA*; BURGER, JR; FRISTOE, TS; KHALIQ, I; HOF, C; SMITH, FA; National Museum of Natural History, University of North Carolina, Washington University, St. Louis, Senckenberg Biodiversity and Climate Research Centre , University of New Mexico; *BalkM@si.edu*

Constraints and trade-offs in endotherm thermal regulation: implications for climate adaptations

Surprisingly, the thermal tolerances of species often do not match the range of environmental temperatures experienced within in the geographic range. Although a variety of hypotheses have been proposed to link thermal physiology and the thermal niche, support for these relationships is not consistent between taxonomic groups. According to the Scholander-Irving model of thermal physiology, a trade-off between the upper (T_{UC}) and lower (T_{LC}) bounds of the thermal neutral zone is predicted for endotherms. Such a trade-off may explain the discordance between species' thermal tolerance and their thermal environment. Here, we employ a dataset of 297 mammal and 134 non-migratory bird thermal physiology to test for the predicted trade-off as well as investigate its role in the mismatch between species' thermal physiology and their thermal environment. We show that a trade-off does indeed exist between upper and lower thermal critical temperatures for the majority of mammals and birds. Further, we find that the trade-off is asymmetrical with an increase in T_{UC} corresponding to a disproportionate increase in T_{LC}. Additionally, the trade-off plays a significant role in the mismatch between species' thermal tolerances and their thermal environment. Evidence of this trade-off means that strong physiological constraints limit adaptations to extreme environmental temperatures.

20-6 BALLESTEROS, JA*; SHARMA, P; Univ. of Wisconsin, Madison; *ballesterosc@wisc.edu*

The Evolution Of The Chelicerate Genome: Sorting Out Gene Expansions In Old Radiations

Chelicerates are one of the three main groups of extant arthropods, along with myriapods (millipedes and centipedes) and Pancrustacea (insects and crustaceans). While more diverse in previous geologic eras, extant chelicerates consist of three groups: horseshoe crabs (Xiphosura), sea spiders (Pycnogonida) and arachnids (Arachnida). Extant arachnids are almost exclusively terrestrial, Xiphosura and Pycnogonida are restricted to marine environments. The available draft genomes of xiphosurans and some arachnids have shown the presence of gene duplicates, potentially derived from ancestral genome duplications, but the extent, pattern, and tempo of such gene expansions remain poorly understood. The relationships of chelicerate groups have been elusive even with genomic data at hand. A recurrent pattern in these analyses, commonly attributed to systematic biases, breaks the monophyly of Arachnida by including xiphosurans as a nested clade, albeit with unstable affinities. We used combination of genomic data (transcriptomes and genomes) to identify gene families and produce a species tree based on traceable hypotheses of orthology. The resulting species tree echoes previous results by placing Xiphosura within the arachnid clade. Here, we use the composition and relationship of these individual gene copies to investigate the extent, pattern and tempo of the gene expansion with emphasis on representative gene families. Based on the empirical species tree, we conducted coalescent gene-tree simulations to evaluate the potential effects of incomplete lineage sorting on our ability to distinguish competing hypotheses. Our main goal is to investigate the link of the observed gene expansions and their potential role in macroevolutionary phenomena such as the transition to terrestrial environments.

P3-206 BALLINGER, MA*; LIN, J; LONGO, T; HEYER, GP; PHIFER-RIXEY, M; FERRIS, KG; NACHMAN, MW; Univ. of California, Berkeley, Monmouth Univ., Monmouth Univ., Univ. of California, Davis; *mallory.ballinger@berkeley.edu*

Phenotypic Variation between Temperate and Tropical Populations of House Mice

House mice, Mus musculus domesticus, have recently expanded their range across the Americas, encompassing diverse habitats ranging from tropical to arctic climates. The challenges of adapting to different temperature, precipitation, and seasonal regimes make house mice an ideal system for understanding the genomic and physiological bases of rapid environmental adaptation. Using brother-sister mating, we are creating new wild-derived strains mice from five different populations in North and South America. Using these new strains, we found morphological differences among populations consistent with both Bergmann's rule and Allen's rule: mice from New York are larger and have shorter ears and tails than mice from Brazil. Moreover, mice from New York are larger, build bigger nests, and are more active than mice from Brazil. Lastly, house mice from New York and Canada have larger average litter sizes than mice from Brazil. These differences persist in the lab over multiple generations indicating that they have a genetic basis. We conclude that despite recent introduction to the Americas, house mice have undergone rapid adaptation to various environments.

P1-195 BANAHENE, N*; SALEM, S; BYRNE, H; GLACKIN, M; THOMPSON, L; FASKE, T; AGOSTA, S; ECKERT, A; GRAYSON, K; Univ. of Richmond, VA, Virginia Commonwealth Univ., Richmond, Virginia Commonwealth Univ., Richmond; *nanakonadu.banahene@richmond.edu*

Stage-Specific Responses to Heat Stress in an Invasive Forest Pest

Understanding the role of climatic limits for invasive species is important for determining future range dynamics. The spread of the gypsy moth (*Lymantria dispar*) across wide climatic gradients in North America provides an ideal system for studying the role of thermal limits in invasion. Previous work has shown that spread rate variability at the southern invasion front is correlated with supraoptimal temperatures. Here, gypsy moth individuals were exposed to daily temperature ramping cycles of optimal (22-28°C) or supraoptimal temperature treatments (30-36°C, 32-38°C, or 34-40°C) at specific developmental stages (1st through 4th instar, pupa) for either 2 or 7 days. We measured survival and long term effects on development time and pupal mass. Survival generally decreased as temperature increased. The 34-40°C treatment had the largest effect on larval survival, with 7 days of exposure being lethal for all stages except 2nd instar and pupae. All other treatments had more than 75% survival after 7 days for all stages. Long term effects of 2 day exposure to heat were more pronounced for females than males and exposure at later larval stages resulted in larger decreases in pupal mass. These negative effects of high temperature exposure support spread patterns seen at the southern invasion front and provide important data on the susceptibility of gypsy moth to high temperatures at different developmental stages. As global temperatures rise, understanding how temperature influences the spread of invasive populations will be critical for management decisions.

P1-133 BANKER, SE*; NACHMAN, MW; Univ. of California, Berkeley; *sarah_banker@berkeley.edu*

Patterns of adaptive introgression between sister species Mus musculus domesticus and Mus spretus

Adaptation requires genetic variation upon which natural selection can act. There are three major sources of genetic variation: (1) new mutations, (2) standing genetic variation, and (3) introgressed variants from other species. Introgressed variants are especially intriguing because they may arise faster than new mutations, can include multiple mutations on a single haplotype, and have been tested by selection in the species of origin. Mus musculus and M. spretus diverged an estimated 1.5-3 Mya, have a genetic divergence of about 1%, and are broadly sympatric. The two species have many morphological and life history differences. Additionally, there is a significant fitness disadvantage to hybrids; F1 males are completely sterile and genomic incompatibilities exist between the two species. Several previous studies have revealed introgression of alleles from M. spretus into M. musculus. Here we find evidence for directional introgression from M. m. domesticus into M. spretus populations at over 100 genomic regions, with high variability of introgression patterns between individuals. Additionally, we used selection tests to categorize these introgressed regions as neutral or putatively adaptive.

P2-256 BARAN, NM*; STREELMAN, JT; Georgia Institute of Technology, Atlanta; *nicole.baran@biology.gatech.edu*

Species Differences in Aggressive Behavior, Neural Activity, and Brain Gene Expression in Lake Malawi Cichlid Fish

In Lake Malawi, two ecologically distinct lineages of cichlid fishes (rock- versus sand-dwelling ecotypes, each comprised of over 200 species) evolved from a single ancestral population within the last million years. The rock-dwelling species (Mbuna) are aggressively territorial year-round and males court and spawn with females over rocky substrate. In contrast, males of sand-dwelling species are not territorial and instead aggregate on seasonal breeding leks in which males construct courtship "bowers" in the sand. First, we demonstrate species and ecotype differences in behavior using mirror-elicited aggression tests in seven species. We find that, in general, rock-dwelling species attack their reflection faster and perform more frontal attacks. In contrast, sand species perform more lateral displays (orienting laterally and displaying their colors). Second, using one rock species (*Petrotilapia chtimba*, Petro), and one sand species (*Mchenga conophoros*, MC), we compare neural activity following mirror-elicited aggression in three brain regions with known roles in aggression in fish: Dorsal medial telencephalon (Dm), dorsolateral telencephalon (DI), and the preoptic area (POA). Finally, we use phosphorylated ribosome immunoprecipitation of mRNA from whole brain followed by RNA-sequencing to compare the gene expression patterns of neurons activated by mirror-elicited aggression across the two species. Due to their recent evolutionary divergence, multiple rock and sand species have been hybridized in the lab. Thus, this work lays the foundation for future experiments using this emerging genetic model system to investigate the genomic basis of evolved species differences in both brain and behavior.

P1-162 BARNES, DK*; ALLEN, JD; College of William and Mary; *dbarnes@email.wm.edu*

Effects of delayed hatching on echinoid larval development

Environmentally cued hatching is present in diverse phyla in response to biotic and abiotic factors including temperature, tidal inundation, and predator cues. Echinoderms have been shown to delay hatching in response to salinity reductions during early development. In the sand dollar *Echinarachnius parma*, embryos exposed to low salinities early in development can delay hatching up to early pluteus larval stages. Embryos that delay hatching appear to continue normal development, but confinement within the fertilization envelope prevents larval arms from growing as long as those of hatched individuals. The fertilization envelope also acts as a barrier, preventing larvae from ingesting the algal cells they might otherwise consume. As a result, costs of delayed hatching could result from shorter arms, delayed access to algal food, or both. To distinguish between these alternative possibilities, we conducted an experiment with five treatments, each containing sibling embryos that had: 1) hatched at 18 hours post fertilization (hpf) in normal salinity (~33 ppt) with food present, 2) hatched at 18 hpf in normal salinity with delayed availability of food, 3) hatched at 18 hpf in low salinity (26 ppt) with food present, 4) hatched at 18 hpf in low salinity with delayed availability of food, and 5) hatched at 38-40 hpf at low salinity with food present (n = 4-5 replicates per treatment). Five larvae from each replicate were photographed weekly to record arm and body lengths. Juvenile size, spine number, and spine length were also measured after settlement. The strongest treatment effects were related to pre-hatching salinity. Larvae at lower salinities were more likely to be asymmetrical than their siblings but, counterintuitively, exhibited a higher degree of competence when challenged to metamorphose.

101-1 BARNES, BM*; WILLIAMS, CT; BUCK, CL; SHERIFF, MJ; RICHTER, MM; KRAUSE, JS; Univ of Alaska Fairbanks, Northern Arizona Univ, Penn State Univ, Western Kentucky Univ, Univ of California, Davis; *bmbarnes@alaska.edu*

Sex-dependent phenological plasticity in an arctic hibernator

Hibernation provides a highly programmed means of escaping the metabolic and food availability challenges associated with seasonality, but the ability of small mammalian hibernators to adjust their timing of seasonal dormancy in response to extreme weather events is unclear. Here, we show that arctic ground squirrels in Northern Alaska exhibited sex-dependent plasticity in the spring-time physiology and phenology of hibernation-end in response to a series of late spring snowstorms in 2013 that resulted in the latest date of snow-melt on record. Females and non-reproductive males responded to the >1 month delay in snow-melt by extending heterothermy or re-entering hibernation after several days of euthermy, leading to a >2-week delay in reproduction compared to surrounding years. Females increased the frequency of arousal episodes and assessed above ground conditions, presumably the extent of snow-cover, before committing to above-ground activity and reproduction. In contrast, reproductive males neither extended nor re-entered hibernation and emerged from hibernation normally, likely because seasonal gonadal growth and development and subsequent testosterone release prevents a return to torpor. Our findings reveal intriguing differences in responses of males and females to climatic variability that can generate a phenological mismatch between the sexes.

17-4 BARNES, CL*; HAWLENA, D; MCCUE, MD; WILDER, SM; Oklahoma State University, The Hebrew University of Jerusalem, St. Mary's University; *cody.l.barnes@okstate.edu*

Consequences of Prey Exoskeleton Content for Predator Feeding and Digestion

The arthropod exoskeleton provides structure and protection. Exoskeleton mass varies widely both within and between insect taxonomic groups. Further, the exoskeleton can be rigid and largely indigestible for predators. Potential consequences of insect prey exoskeleton for predators include increased handling time, greater digestive metabolism cost, and reduced nutrient assimilation. But, the consequences of feeding on chitinous prey could vary with predator foraging and consumptive modes. We tested the consequences of prey exoskeleton content for nutrient assimilation and digestive bioenergetics of two spiders that differ in feeding mode: a wolf spider (masticator) and black widow (piercer). We predicted lower assimilation and higher digestive costs when feeding on the more chitinous beetles compared to mealworm larvae. We found that less elements (C and N), macronutrients (lipid and protein), and energy were extracted from highly chitinous prey. In particular, black widows deposited adult beetle carcasses with greater protein and energetic content than mealworm carcasses. Although handling time and digestive metabolism (Specific Dynamic Action) did not differ, spiders allocated a greater proportion of prey energy (SDA coefficient) in digestion of more chitinous adult beetles. The feeding and digestive consequences we observed suggest that exoskeleton is an attribute that influences foraging benefits and resource allocation by predators. The digestive modes of predators additionally contributed to differences in the extraction of nutrients from chitinous prey. Future study should further explore the mechanisms by which predator resource intake and deposition from prey varying in exoskeleton content, integrating multiple resource perspectives, contributes to broader ecosystem resource flow.

P3-250 BARRAGAN, Y*; LAURETTA, D; RODRIGUEZ, E; Universidad Autónoma de Baja California Sur, La Paz, Museo Argentino de Ciencias Naturales Bernardino Rivadavia, Buenos Aires, American Museum of Natural History, New York; *yamaly.barragan@gmail.com*

Revision of the Genus Actinostella (Cnidaria: Actiniaria: Actinioidea) from Tropical and Subtropical Western Atlantic and Eastern Pacific: Redescriptions, Synonymies and Sister Species

Sea anemone species of the genus *Actinostella* live in tropical and subtropical shallow waters, hiding in crevices or burrowed in the sand. They are characterized by having a marginal ruff harboring zooxanthellae that expands during the day to optimize photosynthesis and retracts at night allowing the anemone to catch prey with the tentacles. Currently, 10 species are considered valid; however, most of the species within the genus were described in 1800's or in early 1900's and thus most of the descriptions are incomplete according to nowadays standards. Several species of *Actinostella* have reported distributions covering both, the Caribbean Sea and the Pacific Ocean. The morphological and molecular revision of this genus aims to corroborate species identities and potential synonymies within the genus. This study will allow to elucidate if species of *Actinostella* distributed in both ocean basins (Atlantic and Pacific) were separated with the appearance of the Panama Isthmus, or are more related to species at each corresponding ocean basin (i.e. Atlantic - Pacific). In case of finding sister species separated by the Isthmus of Panama, they will represent the first calibration nodes for the phylogenetic history of sea anemones, a group of soft-bodied corals lacking fossils.

P2-125 BARREIRA, SN*; BAXEVANIS, AD; National Institutes of Health; *sofia.barreira@nih.gov*

Exploring the Role of Large Tandem DNA Repeats in the Context of Regeneration

Repetitive DNA has been implicated in chromatin organization, genome replication, expression regulation, and cell proliferation. Chromosomal regions that contain large tandem repeats such as ribosomal genes, telomeres, and centromeres are often not included in the reference genomes of most model organisms. We are currently sequencing and assembling the genome of *Hydractinia*, an organism that has proven to be a valuable model for the study of regenerative medicine, early development processes, and allorecognition. Like human embryonic stem cells, *Hydractinia* stem cells are pluripotent; homologs for many genes associated with the ability to self-renew and differentiate in bilaterians have already been identified in *Hydractinia*, reinforcing its value in the study of development and regeneration. Importantly, the regenerative process also depends on both the maintenance of telomere integrity throughout numerous cycles of cell division and the role of ribosome biogenesis in cell growth and proliferation. To better understand the role of repetitive DNA in regeneration and stem cell maintenance in *Hydractinia*, we are characterizing the large tandem repeats in these de novo assemblies, as well as studying protein complexes that interact with and help regulate their function. We have already identified a ribosomal gene consensus sequence and prospective junction sequences on either side of rDNA clusters that may play a role in ribosome regulation. Using the eukaryotic telomeric sequence, we have also identified scaffolds that flank the telomere and contain new tandem repeats up to 380 bp in length. These findings represent a critical first step towards understanding how differences in the genomic structure of these highly repetitive regions may confer and control regenerative capacity.

P3-56 BARRETO, KM*; FRANCIA, MR; CLAUDIO, I; FANFAN, N; SEGARRA, A; BARTHELL, JF; ABRAMSON, C; GIRAY, T; AGOSTO-RIVERA, JL; Univ. of Puerto Rico, Mayaguez , Univ. of Puerto Rico, Rio Piedras , Univ. of Puerto Rico Medical Sciences, Univ. of Central Oklahoma, Oklahoma State Univ.; *kelly.barreto1@upr.edu*

Immunofluorescence Staining Method Optimization for Honeybee Brains

Honeybees have been used as a model organism for learning, behavior and memory. Brain imaging techniques are fundamental for understanding how the brain works. Immunofluorescence labeling combined with confocal microscopy is a powerful approach to understand behavior from a molecular standpoint. However, this technique is associated with signal-noise issues related to autofluorescence, fixation and light penetrance. In this study, we sought to optimize conditions for staining whole mount Honeybee brains by decreasing fixation-related autofluorescence using $NaBH_4$ and increase light penetrance using brain clearing methods. Bee heads were fixed in formaldehyde and stored in a glycol-based antifreeze to preserve the tissue, then brains were incubated with $NaBH_4$. Immunohistochemical assays were conducted for pigment dispensing factor-PDF. Focus Clear™, a reagent that increases tissue transparency was used before mounting. Results show that autofluorescence is reduced when combining $NaBH_4$ with Triton, a detergent that increases tissue permeability. One-way ANOVA analysis on average fluorescence intensity shows significant differences between the untreated and treated samples. Images taken from the confocal microscope show a higher amount of optical sections for brains treated with clearing agent due to improved light penetrance on the tissue. Brains incubated with anti-PDF did not exhibit immunoreactivity. All data shows the techniques used helped reduce autofluorescence and increase light penetration.

P1-223 BARRETT, L.M.*; DEAROLF, J.L.; THOMETZ, N.M.; BRYAN, A.; REICHMUTH, C.; HENDRIX COLLEGE, CONWAY, AR, UNIV. OF SAN FRANCISCO, CA, ALASKA DEPARTMENT OF FISH AND GAME, FAIRBANKS, UNIV. OF CALIFORNIA, SANTA CRUZ; *barrettll@hendrix.edu*

Fiber-type composition of bearded seal (Erignathus barbatus) locomotor muscle

Bearded seals (*Erignathus barbatus*) are ice-associated pinnipeds (seals, sea lions, and walruses) that forage benthically. These animals are vulnerable to sea ice loss caused by global climate change. As such, understanding more about the unique physiology of this seal compared to other pinnipeds is important. One approach is to examine the construction of their swimming muscles. In this study, we examine and report the fiber-type profile of one of the bearded seals' locomotor muscles, the longissimus dorsi (LD). Sections of seven bearded seal LDs were cut using a cryostat and stained for their myosin ATPase activity after basic pre-incubation, as well as for their reaction to myosin heavy chain antibodies (A4.951 - slow myosin; SC-71 - fast IIa myosin). The stained sections were imaged, and the fibers on the ATPase images were placed into three categories: dark, intermediate, and light. The numbers of fibers in each category were counted, and these abundance data were used to calculate the average fiber-type profile of the bearded seal LD. Additionally, the diameters of fibers in each of the three categories were measured using ImageJ. These properties of bearded seal swimming muscles will be evaluated in the context of complementary physiological data now available for this species. Furthermore, their fiber-type profile and fiber diameters will be compared to those of the locomotor muscles of other seals, to enable an improved understanding of the species-specific characteristics of bearded seal muscle.

71-3 BARTS, N*; NIEVES, N; TOBLER, M; Kansas State University; *barts2@ksu.edu*

Metabolic Physiology of Extremophile Fish Inhabiting Hydrogen Sulfide-Rich Environments

Extreme environments are characterized by physiochemical conditions that are stressful for most organisms, often resulting in modifications to organismal biology. Metabolism is critically important for an organism's ability to respond to environmental stress, as it is directly tied to energy homeostasis. This may be especially important for organisms that inhabit hydrogen sulfide (H2S) environments. H2S directly binds to cytochrome c oxidase, disrupting electron transport and inhibiting aerobic ATP production. Theory suggests that this should result in modifications of metabolic physiology in organisms that persist in these toxic environments, however, few studies have addressed this hypothesis in natural systems. To test whether variation in metabolic physiology exists between sulfidic and non-sulfidic populations, we measured the metabolic rates of two population pairs of *Poecilia mexicana*. *P. mexicana* has repeatedly colonized H2S springs in Southern Mexico. These replicated colonization events allow for the comparison of physiological mechanisms used to cope with the extreme conditions imposed in these habitats. We used intermittent-flow respirometry to compare standard metabolic rate (SMR), maximum metabolic rate (MMR), and aerobic scope (AS) under non-sulfidic conditions and closed-chamber respirometry to measure RMR under both sulfidic and non-sulfidic conditions. We found that SMR was significantly increased in one population of sulfide spring fish, but there were no differences in MMR or AS across all populations measured. Fish from sulfidic populations were able to maintain RMR upon exposure to H2S, while the non-sulfidic populations showed a significant decrease in metabolic rates. This study provides insight into the physiological mechanisms organisms use to maintain energy homeostasis under extreme environmental conditions.

P1-95 BARTS, N*; TOBLER, M; Kansas State University; *barts2@ksu.edu*

Regulators or Conformers? Mechanisms of Sulfide Tolerance in an Extremophile Fish

Under environmental stress, organisms may adopt two strategies to allow for maintenance of organismal function: regulation, in which organisms actively regulate internal concentrations of a substance to maintain homeostasis, or conformity, in which internal concentrations of a substance match that of the environment. Hydrogen sulfide (H2S) environments provide a unique opportunity to test how these strategies may facilitate adaptation to harsh environments because the candidate pathways for both conformity (modification of toxicity targets) and regulation (modification of detoxification enzymes) are known. H2S is a respiratory toxicant that inhibits cytochrome c oxidase (COX), which halts aerobic ATP production, and is regulated by the sulfide:quinone oxidoreductase (SQR) pathway. Despite the toxicity, populations of *Poecilia mexicana* are known to inhabit sulfidic and non-sulfidic streams in replicated river drainages. This replication provides an opportunity to compare mechanisms of adaptation in response to a single source of selection. Genomic data indicates evidence for conformity (evolution of a sulfide-resistant COX) and regulation (increased gene expression of the SQR pathway), but the importance of either mechanism likely varies among populations. If fish are regulators, tolerant and non-tolerant populations should differ in the threshold at which maintenance of homeostasis fails, but if they are conformers, they should differ in the endogenous concentration of sulfide that results in loss of organismal function. To measure mechanisms of sulfide tolerance, I utilized mitoA, a molecular probe that binds H2S in the mitochondria, to determine how internal sulfide concentrations scale upon exposure to environmental H2S across different tissues in two population pairs of *P. mexicana*. This approach allows us to functionally test alternative hypotheses generated from next generation sequencing data.

P1-250 BASHAR, SJ*; LOPEZ, K; FUSE, M; San Francisco State University; *sbashar@mail.sfsu.edu*

Assessing systemic responses to imaginal disc damage in the hornworm, Manduca sexta

A fundamental question in biology is how do organisms sense and assess tissue development in proportion to the growth of the whole body. Growth delay during metamorphosis, the "puberty" phase in insects, is observed in a number of holometabolous insects when there is local damage to regenerative tissue such as the imaginal discs. An unexpected benefit of the delay is a period for damaged cells to regenerate and minimize disruptions in body allometry. This project attempts to characterize the mechanism of communication between damaged imaginal discs and the endocrine center in the hornworm, *Manduca sexta*. It is hypothesized that the hemolymph (blood) carries secreted factor(s) to the endocrine centers and delays production or release of developmental hormones required to initiate adult eclosion. In this study, we used SDS-PAGE and western blot to measure changes in **(i)** developmental hormones via phosphorylation of the downstream ERK/RSK signaling cascade, and **(ii)** protein abundance in hemolymph of the damaged larvae, including insulin-like proteins previously identified as the delay factor secreted in *Drosophila melanogaster*. This data should ascertain in *M. sexta* which signals are released from damaged imaginal discs, and that target endocrine systems to delay development. Identifying the developmental delay mechanism in *M. sexta* will provide further insight for how organisms adapt to disturbances in tissue development and may help us understand similar puberty delays in human inflammatory diseases. It may also provide a new model system for addressing the interactions of insulin-like-peptide and developmental hormones in growth and development in insects.

P3-108 BASHIER, R*; ALVARADO, S; FERNALD, R; Stanford University; *rbashier@stanford.edu*

Neural substrates within two color morphs of Astatotilapia burtoni

Dynamic coloration is an important trait for concealment and social communication in animals. Among cichlid fish species, coloration is particularly important for males and their nuptial displays. The African cichlid *Astatotilapia burtoni* naturally exist in two color morphs, blue and yellow, in the wild and within laboratory rearing conditions. Furthermore, dominant males are territorial, sexually active, and aggressive with a rich behavioral repertoire while their non-dominant counterparts are drably colored non-territorial males who cannot mate and have a far smaller behavioral repertoire. Body color in *A. burtoni* is an important social signal with males increasing the intensity of their color with a higher social status. Previous work from our lab has shown that blue and yellow morphs confer different social outcomes, with yellow males acting more aggressively and winning more fights for dominance over blue males, with each morph having different physiological profiles. In this current study, we compare the behavioral and neural correlates between blue and yellow morphs of *A. burtoni* that we generated in the lab. We employed the use of behavioral scoring and phospho S6 staining to identify neuronal correlates of behavior to specific parts of the brain.

81-5 BATTISTA, NA*; MILLER, LA; The College of New Jersey, University of North Carolina at Chapel Hill; *battistn@tcnj.edu*

A fully coupled fluid-structure-muscle-electrophysiology model in heart development

The vertebrate heart begins to pump when its morphology resembles a simple valveless tube. The tube is composed of an outer layer of myocardial cells surrounding an inner layer of endocardial cells. It has been proposed that the purpose of the embyronic heartbeat is to aid in the growth and shaping of the heart itself in organogenesis, rather than the delivery of oxygen and nutrients. Heart tubes have been previously described as either peristaltic and impedance pumps. Impedance pumping assumes a single actuation point of contraction, while traditional peristalsis assumes a traveling wave of actuation. In addition to differences in flow, this inherently implies differences in the conduction system, where possible transitions from one pumping mechanism to the other may be possible via a change in action potential diffusivity. Using an open source implementation of the immersed boundary method, *IB2d* , we developed a fully coupled fluid-structure-muscle-electrophysiology model of the embryonic heart. We find that differences in the resulting pumping behavior, greatly affects the advection and diffusion of a chemical gradient within the heart tube. These chemical gradients, e.g., morphogens, could serve as an essential epigenetic signal required for proper cardiogenesis

102-1 BATTLES, AC*; KOLBE, JJ; University of Rhode Island; *ANDREWCBATTLES@GMAIL.COM*

Costs and benefits of urbanization on lizard locomotor performance

Urbanization alters natural habitat in drastic ways, changing the structural habitat from forests to buildings and roads, which also increases local temperature, known as the urban heat island effect. Some species persist under these conditions, but few mechanistic studies exist that assess how organisms adjust to the novel conditions in cities. Anolis lizards are an ideal system to test the effects of urbanization on locomotor performance because they are particularly sensitive to changes in the structural habitat, a key axis of diversification for anoles, and changes in environmental temperature because they are ectotherms. But, such disruptions may not necessarily reduce fitness or influence persistence. Field studies in Miami show that urban areas have an increased proportion of smooth, vertical structures and that they tend to be warmer than nearby natural forested sites. In performance trials on tracks that vary in incline and substrate roughness, we predict that two species of anoles, *Anolis cristatellus* and *Anolis sagrei*, will perform worse when running on smooth, vertical substrates, and will change limb postures to increase stability. We found that both species sprint slower and slip and pause more often on smooth, vertical substrates compared to an inclined bark substrate. Because operative temperatures, the body temperature of a lizard not actively thermoregulating, are higher in urban areas, we expected, but did not find, that urban lizard populations have higher optimal performance temperatures. However, the greater availability of warm microclimates in urban habitats may allow lizards to utilize a greater portion of their optimal performance capabilities. We demonstrate that different components of urbanization may influence persistence in opposing directions; performance decreases due to moving on smooth structures in urban areas, yet increases from a thermal perspective due to warmer microclimates available in cities.

P1-41 BATZEL, G*; LYONS, DC; Scripps Institution of Oceanography, UC San Diego; *gbatzel@ucsd.edu*

Elucidating the molecular mechanisms for biomineralization using the slipper-snail Crepidula (Gastropoda: Calyptraeidae)

Animals underwent a period of rapid evolution around 500 million years ago, in what is now referred to as the Cambrian explosion. The majority of extant phyla descending from that period include organisms that possess the ability to biomineralize. Large datasets of transcriptomic and proteomic information have been generated to assess whether a conserved biomineralization toolkit exists among Metazoa. However, a purely bioinformatics approach is unable to reveal how a gene's function contributes to biomineralization. It is still not determined whether the gene networks controlling biomineralization in different taxa are conserved, or whether biomineralization has evolved independently in the metazoan lineage. To address this, we are using the calyptraeid gastropod, *Crepidula*, as a model organism to understand biomineralization among mollusks. *Crepidula* is amenable to genetic perturbation studies like CRISPR, morpholinos, and overexpression studies, allowing for functional perturbation of genes expressed in the shell gland. The cell lineages that give rise to the shell gland are known, and we have screened transcriptomes for genes involved in shell patterning and biomineralization in developing embryos and larvae of *Crepidula fornicata*. Expression of the genes within the shell gland may reveal putative roles in biomineralization. The data will be used to construct a biomineralization gene regulatory network in a gastropod mollusk, allowing for comparative studies to be taken among other calcifying members in the Metazoa.

P1-262 BAUMGART, A*; ANDERSON, P; University of Illinois, Urbana-Champaign; *baumgrt2@illinois.edu*

Mechanical sensitivity of the cranial linkage in Salmo salar

Understanding the mechanics behind morphological systems offers insights into their evolution. Recent work on linkage systems in fish and crustaceans has suggested that the evolution of such systems may depend on mechanical sensitivity, where geometrical changes to different parts of a system can have variable influence on mechanical outputs. While examined at the evolutionary level, no study has tested directly for mechanical sensitivity within a biological linkage system at the mechanical level. In this study, we analyze the mechanical sensitivity of three mechanical outputs of the fish cranial linkage. We examine three measures of kinematic transmission (KT, the ratio of output link to input link rotation) based on a neurocranium input link and three output links: the suspensorium, hyoid, and lower jaw. We investigate two specific questions about the sensitivity of these outputs to changes in linkage geometry: 1) What changes in linkage geometry affect the KT of one output link while keeping the other KTs constant? 2) Which geometry changes result in the largest and smallest changes to each KT? We addressed these questions using a kinematic model based on the cranial linkage of *Salmo salar* available from the R package linkR. We systematically changed the linkage geometry by altering the positions of each joint and calculating the resulting KTs. Our results show that 1) it is possible to change the geometry such that each KT can be altered without affecting the others, and 2) there are multiple ways to alter link length, some of which influence KTs more than others. These results provide insight into the morphological evolution of the fish skull and highlight which structural features in the system may have more freedom to evolve than others, demonstrating the value of applying mechanics to organismal evolution.

116-3 BAUMGART, SL; Univ. of Chicago; *slbaumgart@uchicago.edu*

Does Body Mass Constrain Avian Wing Shape or Sternum Shape?

Two factors central to flight mechanics in birds are forces exerted by the flight muscles on the wing and wing shape that governs its aerodynamics. Wing shape has been linked to behavior, but comprehensive morphometric analysis of avian sternum shape has yet to be conducted, even though the sternum anchors the major flight muscles and its morphology is very diverse throughout Aves. Keel shape and size correlate strongly with flight muscle mass and keel position with mechanical advantage. Tracking disparity in wing and sternum morphology would provide a structural basis for comparing flight mechanics between modern birds and extinct taxa. Here, I examine wings and sterna of 82 "water birds" using two-dimensional geometric morphometrics on images of wings and of ventral and lateral sternal surfaces by applying both homologous landmarks and semi-landmarks. The resulting phylomorphospaces and statistical analyses reveal a high degree of convergence in both wing shape and sternum shape. Mapping body mass onto these phylomorphospaces suggests that body mass has less effect on constraining wing shape than sternum shape. The plot of wing shape space shows a relatively even scatter of low and high body masses throughout the occupied shape space. The ventral and lateral sternum shape spaces show significantly greater clustering within birds of smaller body masses and a wide spread of sternal shapes within birds of larger body masses. These results suggest that sternum morphology should be taken into account and analyzed with wing shape to more fully test coevolution, convergence, and disparity of functional adaptations in the forelimb and girdle for powered flight.

83-3 BAUMS, IB*; DEVLIN-DURANTE, M; Pennsylvania State University; *baums@psu.edu*

Probing mechanisms of coral acclimatization

Acclimatization is a non-genetic process by which an individual organism heightens its stress tolerance after exposure to a stressor. Understanding mechanisms by which corals acclimatize is urgent given their large population declines in response to increasing temperatures. There is growing interest in the role methylation changes play in coral acclimatization and phenotypic plasticity. However, because reef-building corals harbor intracellular symbionts (genus *Symbiodinium*), discerning the relative contribution of host and symbiont to acclimatization can be difficult. The Caribbean elkhorn coral, *Acropora palmata*, has an uncomplicated symbiosis: it associates with just one symbiont species (*S. 'fitti'*) and most colonies also harbor only one strain of *S. 'fitti'*. August of 2014 was the warmest on record for the Florida Keys. By early September 2014, numerous corals species bleached throughout the Florida Keys reef tract. This event provided an unprecedented opportunity to understand whether methylation status contributes to acclimatization and plasticity in reef corals. Initial surveys of *Acropora palmata* documented a range of bleaching response. This response varied between reefs but also within single, monoclonal stands of *A. palmata*. Thus, coral clonemates were observed to exhibit different bleaching susceptibilities despite sharing identical (clonal) *Symbiodinium* communities. Similarly, 16s tag sequencing data failed to provide evidence for a correlation between other microbiome members and the hosts bleaching response. Instead, reduced representation sequencing of the methylated sites within the coral hosts' genome indicated a role for methylation differences in contributing to host acclimatization. Further study of epigenetic mechanism contributing to coral acclimatization and plasticity are warranted in the light of rapidly changing shallow marine environments.

P2-214 BAXTER, CA*; PEPPER, RE; University of Puget Sound; *cbbaxter@pugetsound.edu*

Single Versus Group Feeding Patterns in Vorticella convalleria

Microscopic sessile suspension feeders (MSSFs) are single-celled eukaryotes that live in aquatic environments attached to surfaces. They play a pivotal role in carbon cycling, filter 10-25% of coastal surface water each day, and can remove significant amounts of heavy metals from industrial wastewaters. MSSFs feed on bacteria and debris by creating a fluid flow that varies at different cell body orientations to the surface. When MSSFs feed with their body at an angle to the surface, they filter four times more water than if perpendicular. Previous research has observed that single MSSFs vary this cell body orientation, oscillating angle over time with a consistent pattern. It is unknown why they feed with this pattern, but it is likely important in determining the amount of food intake. Consequently, understanding this oscillating feeding pattern is critical for understanding the impact of MSSF feeding on the carbon cycle. *Vorticella*, a common MSSF, live both singly and in groups; it is possible that different motion patterns may be advantageous for feeding in groups versus alone. Using cultured *Vorticella*, we video recorded either single or paired *Vorticella* under the microscope to determine their orientation relative to the surface of attachment. Orientation was described by finding θ, the polar angle and φ, the azimuthal angle. Motion patterns were compared between single and paired *Vorticella* by comparing several parameters, including amplitude and frequency of oscillation and average angle for both θ and φ. Many attributes of motion were similar between paired and single *Vorticella*; however, the paired *Vorticella* exhibited bigger, slower motion in φ and a slower motion with the same amplitude in θ compared to single *Vorticella*. This opens up the question of whether this slower, larger motion of paired *Vorticella* leads to improved nutrient uptake when *Vorticella* are in close proximity to each other.

103-3 BÖHMER, C; Muséum National d'Histoire Naturelle Paris; *boehmer@vertevo.de*

From Genes to Fossils: Investigating the Evolution of Axial Patterning in Tetrapods through Deep Time

Major evolutionary events in vertebrate evolution were accompanied by substantial changes in the axial skeleton including modifications in the *Hox* genes. These genes are critical regulators of axial differentiation into distinct vertebral regions. In contrast to other tetrapods, mammals and turtles are constrained in cervical count and, hence cervicodorsal regionalization. This raises the question if the numerical constraint is associated with a common *Hox* code not present in their non-constrained extinct relatives. On the basis of recent works that revealed a correlation between anterior *Hox* gene expression and vertebral shape, I investigated the cervical vertebral column of living and fossil mammals and turtles via 3D geometric morphometrics. The statistical assessment of shape changes between successive vertebrae enabled the establishment of the morphological subunit patterns in the neck of each taxon which is interpreted to reflect the *Hox* code. The results indicate that the modularity in the neck of the model organism mouse had already been established in the last common ancestor of mammals, but it differed from that of non-mammalian synapsids which display variable cervical counts. Thus, the constrained cervical count in mammals is likely to be associated with a common *Hox* code not present in early synapsids. During the evolution towards modern turtles the modularity of the neck diverged into a pleurodiran- and a cryptodiran-specific pattern which appears to be linked to their respective neck retraction mode. Despite the numerical constraint, the *Hox* code is likely to have been modified in turtles. The present study provides an important basis for future work investigating the factors that may restrict flexibility in axial patterning in tetrapods.

P3-171 BÖHMER, C*; PLATEAU, O; CORNETTE, R; ABOURACHID, A; Muséum National d'Histoire Naturelle Paris; *boehmer@vertevo.de*

What is a Long Neck? The Effects of Scaling Relationships between Skeletal Dimensions and Body Size in Birds

Birds constitute a classic example of modern vertebrates with highly variable neck lengths ranging from short necks in songbirds to extremely long, serpentine necks in herons. Since this includes a wide array of small to very large species, this raises the question of how neck length relates to body size. Furthermore, neck length is not necessarily an indicator of the number of cervical vertebrae since a few elongated vertebrae may form an equally long neck as do many short vertebrae. Despite their long necks, the long-legged flamingos have only 19 cervical vertebrae, whereas the necks of the short-legged swans display 26 cervical vertebrae. This leads to the second question of whether there is a relation between the length of cervical vertebrae and other parts of the body. Here, we sampled the mounted skeletons of a diversity of bird species (N=82) and compiled quantitative data of body proportions. We tested the length of the cervical vertebrae in relation to body size in order to reveal if the avian neck is subject to allometry. The estimators of body size include body mass and femur length. Next, we analyzed the relationship between vertebral length and the length of other body parts such as skull, trunk, and pelvic limb bones. This enables to reveal trends in proportion between the neck and other parts of the skeleton. In addition to vertebral morphology, vertebral number and size affect the motion and hence function of the avian neck. The present study, as the first large scale analysis of the scaling patterns of the cervical vertebral column in birds, provides an important basis for future work investigating the biomechanical consequences of these factors.

87-7 BEATINI, J.R. *; PROUDFOOT, G.A.; GALL, M.D. ; Vassar College; *jubeatini@vassar.edu*

Effects of Presentation Rate and Onset Time on Auditory Brainstem Responses in Northern Saw-whet Owls

Auditory brainstem responses (ABR), a type of auditory evoked potential, are commonly used to assess auditory processing in avian species. However, the technique has never been used in Northern saw-whet owls (*Aegolius acadicus*), which are known for their unique auditory adaptations and sensitive hearing. Thus, we investigated two common stimulus parameters - repetition rate and onset time - to determine how different features of acoustic stimuli influence the size and shape of the saw-whet owl ABR. There were no differences in the size or synchrony of neural responses at the repetition rates we tested. This suggests that stimuli can be presented to saw-whet owls at a relatively rapid rate to maximize the number of observations from each subject. We also found that noisebursts produced significantly larger and more synchronized responses than tonebursts at onset times longer than 1 ms. The similar size of responses elicited by noise bursts and tonebursts with 1 ms onset times indicates that spectral splatter produces an overgeneralized neural response following the presentation of tones with extremely short onset times. This suggests that stimuli with 2-3 ms onset times should be used in future ABR studies to balance the trade-off between neural response synchrony and spectral splatter.

3-6 BEATTIE, MC*; MOORE, PA; Bowling Green State University; *mollycb@bgsu.edu*

Do Different Diets Fed to Bass (Micropterus salmoides) and Cichlids (Oreochromis aureus x niloticus) Influence Crayfish (Orconectes virilis) Behavior?

Prey often alter their morphology, physiology, and behavior when presented with predatory cues. Alteration in behaviors such as habitat use, activity levels, and fluctuating food consumption are consequences of non-consumptive effects that can alter the dynamics of prey resources and cause changes in food web structure. One of the potentially important key factors in determining predation threat level by predators is the composition of the diet of the predator. We wanted to test the ability of prey to determine threat level based on cues produced by predators on different diets. Two different species of fish, *Micropterus salmoides*, a natural predator of crayfish, and *Oreochromis aureus x niloticus*, a non-natural predator of crayfish, were fed a vegetarian pellet, a protein diet, a heterospecific crayfish, and a conspecific crayfish. Anti-predator behavior was tested by placing the prey (*Orconectes virilis*) in a Y-maze and analyzing the posture, side of choice arena, climbing, walking speed, and shelter usage of the crayfish. Our results show that the diet of the predator and native versus non-native predators alters anti-predatory behaviors in crayfish. It appears as if diet plays an important role in the determination of predatory threat by crayfish.

P1-103 BEATTY , AE*; MARSHALL, HB; GRAZE, RM; SCHWARTZ, TS; Auburn University ; *aeb0084@auburn.edu*

Integrating Research in the Classroom: Causal Effects of IGF1 and IGF2 on Growth in the Brown Anole Hatchling

Recent work has demonstrated that the Insulin and Insulin-like Signaling Network, specifically the Insulin-like Growth Factor (IGF) hormones and their receptors, have been rapidly evolving in reptiles. Studied extensively in mammalian species, these proteins play many essential roles throughout life as key regulators of growth, cell division, metabolism, and lifespan. To address how the rapid evolution of these proteins may have affected their functional role, and the binding affinities with the receptors, it is essential to produce species-specific IGF proteins. To this end, we collaborated with a CURE course focused on rDNA and gene expression at Auburn University. A national surge to incorporate realistic and novel research into laboratory coursework, often integrating a faculty's line of research, has led to the creation of such courses. In the CURE course, IGF1 and IGF2 were cloned, expressed, and purified from the brown anoles and green anoles (*A. sagrei* and *A. carolinensis* respectively). The purified proteins are being used for *in vivo* hormonal injections. Species-specific intraperitoneal injections will be given at four time points (Days 1, 5, 12, and 19) in early development. Snout-vent length, tail length, and mass will be tracked for a period of ten weeks to test each protein's function in early-life growth and results will be discussed. The effectiveness of the CURE curriculum will be analyzed over a period of years. Incorporating the IGF cloning and expression experiment into a classroom setting is the first step in assessing CURE's success, as well as realistically and successfully preparing future scientists.

66-4 BECK, M. L.*; A KAY, C; SEWALL, K. B.; Rivier University, Koc University, Virginia Tech; *beckmichelle@gmail.com*

An Experimental Manipulation of Badge Size in Song Sparrows: Consequences for Male Aggression and Hormone Profiles in Urban and Rural Habitats

Signal honesty is an essential component of stable communication systems, but exposure to novel conditions associated with anthropogenic change has the potential to alter relationships between signals and phenotype, disrupting signaling systems. Previously, we showed that different aspects of melanin-based coloration in male song sparrows related to territorial behavior in urban and rural habitats. Here, we experimentally reduced and enlarged the badge in both habitats, in a balanced design, to determine if associations between badge size and phenotype were plastic across habitats. We assessed the behavioral response to a simulated territorial intrusion prior to manipulation and again two weeks post-manipulation. We also measured body mass and initial corticosterone and testosterone pre and post-manipulation. Based on our previous results, we predicted that males with reduced badges would increase or maintain territorial aggression, have lower body mass, and have greater corticosterone and testosterone concentrations than males with enlarged badges. We found that males with experimentally reduced badges were more aggressive than males with enlarged badges, and that this was particularly the case for urban males. Urban males with reduced badges also lost mass while rural birds and urban males with enlarged badges maintained body mass. However, we found no effect of the manipulation on initial corticosterone or testosterone. Together, these results suggest that melanin ornamentation in male song sparrows mediates territorial interactions and that urbanization influences this response to some extent. However, these behavioral changes are unrelated to initial corticosterone and testosterone concentrations, suggesting an alternative physiological mechanism mediates this relationship.

56-6 BECKER, DJ*; TEITELBAUM, CS; MURRAY, MH; ROZIER, RS; LIPP, EK; HERNANDEZ, SH; ALTIZER, SM; HALL, RJ; Montana State University, University of Georgia; *daniel.becker3@montana.edu*

Disentangling the contributions of intraspecific and exogenous sources of infection on Salmonella transmission dynamics in urbanized white ibis

Urbanization can have interacting and complex effects on wildlife immunology, behavior, and demography with important consequences for exposure to pathogens and sustained transmission. Predicting how urban habituation influences the transmission of multi-host pathogens in a single host species requires a mechanistic understanding of transmission pathways and within-species versus extrinsic sources of infectious propagules. Here we develop a mathematical model for the transmission dynamics of the enteric pathogen *Salmonella* spp. in urban-feeding white ibis (*Eudocimus albus*) to determine (i) the relative importance of close contact versus environmental transmission and (ii) whether sustained transmission can be supported by ibis alone or requires additional non-ibis sources of environmental pathogen stages. Using data on infection prevalence in urban ibis flocks and detections of *Salmonella* in soil and water from the same urban sites within South Florida, we assess support for various transmission routes and sources of infection using Latin hypercube sampling. Across all possible regions of parameter space, simulations that assume low effective contact between ibis, high exposure through environmental uptake, a prevalent non-ibis source of *Salmonella* input into the environment, and high rates of shedding by ibis into the environmental pathogen pool provide the most plausible explanations for the observed temporal patterns in infection prevalence. Our sensitivity analysis therefore suggests that urban white ibis are capable of sustaining seasonal transmission of *Salmonella* in the absence of other environmental sources.

P1-254 BECKER, KB*; CRUZ, A; RANZANI, T; WOOD, RJ; BIEWENER, AA; Harvard; *kbecker@g.harvard.edu*

Exploration of Infundibular Morphology Design Parameters for Optimal Sucker Strength in Cephalopods

Cephalopods can hold onto non-porous substrates with high force for long periods of time while expending minimal muscular energy and are thus particularly inspiring models for soft robots. This is accomplished in part by inducing vacuum with their hydrostatic suckers. In this study, we test the hypothesis that infundibular grooves increase the shear force of suckers by distributing the vacuum of the acetabular chamber to the interface between the infundibulum and the target surface. We show that morphological parameters (shape, size, roughness, direction, and spacing) of grooves and denticles on the infundibulum affect the load-bearing capacity of suckers. To isolate effects of specific parameters, we used 3D printed molds and soft silicone rubbers to fabricate an array of artificial suckers with initial design inspiration taken from Octopus vulgaris. The load capacity of the suckers with an applied internal vacuum of 90kPa was measured for loading angles ranging from 0º (shear) to 90º (normal) using a custom fixture in a tensile testing machine. The load capacity was recorded as the maximal force exerted before failure, (releasing the target surface). Results showed sensitivity to the presence of grooves and denticles in the shear direction but not the normal direction. The highest capacity for designs with a 2 cm wide infundibular disc was 1.7 kg in shear and 1.75kg in the normal direction. Compared to plain suckers with smooth infundibula resembling commercial suction cups, radial grooves increased the shear load capacity of a sucker up to 21% and concentric grooves decreased it up to 31%. The results of this study can be used to better understand the morphological function of suckers and inform the design of artificial soft robotic grasping mechanisms for improved load bearing capacity, dexterity, and energy efficiency.

54-4 BEDORE, CN*; HUETER, RE; JOHNSEN, S; Georgia Southern University, Mote Marine Laboratory, Duke University; *cbedore@georgiasouthern.edu*

Visual Ecology of the White Shark and Shortfin Mako

Visual function in the high-performance and regionally endothermic sharks is assumed to be superior to that of their ectothermic counterparts. These migratory lamnid species, including the white shark (*Carcharodon carcharias*) and the shortfin mako (*Isurus oxyrinchus*), are thought to be visually guided predators with eyes adapted to a wide range of visual habitats. Though shark vision has been of interest to researchers for several decades, most studies are limited to smaller, more accessible species. More recently, greater access to large, predatory species enables us to address outstanding questions regarding the role of vision with respect to their life history traits. To examine visual performance of the white shark and the shortfin mako, we used a visual range model developed by Nilsson et al. (2012). The input parameters included measurements of pupil diameter and focal length, photoreceptor length and peak retinal ganglion cell density, light level, and target size and contrast. Pupil diameter and focal length were measured from incidental mortalities and photographs of live specimens, whereas photoreceptor length and retinal ganglion cell data were taken from previously published data. For sharks viewing a human diver in a black wetsuit in clear, oceanic water, we calculated a visual range of approximately 20m, similar to human vision under the same conditions. However, shark vision is coarser than humans, so less detail is available to sharks for identifying objects using their visual system. Because eye size positively correlates with both sensitivity and acuity, further investigation across both species size ranges will address the functional significance of the visual system with respect to ecological patterns.

S11-1 BENNETT, KD; University of St Andrews; *kdb2@st-andrews.ac.uk*

Intersection of Quaternary climate oscillations and the generation of biodiversity: crucial or irrelevant?

The last 2 million years (Quaternary period) have been a period of dramatic environmental change with major shifts in distributions and abundances of terrestrial and marine organisms. The evolutionary consequences of this were debated during the nineteenth century but the lack of accurate relative and absolute timescales for evolution and environmental change inhibited progress. We do now have an understanding of timescales and detailed palaeoecological work has demonstrated the individualistic nature of species response to environmental change, but lacks a means of determining ancestry. DNA characterization of modern populations in relation to their distributions nicely complements palaeoecological results by contributing ancestry. Both classic palaeoecology and phylogenetics show a remarkable lack of lineage-splitting (speciation) on these timescales, although traditional evolutionary theory leads to the expectation that major environmental changes (such as ice ages) should lead to evolutionary change. This suggests that the factors that lead to lineage-splitting, and hence generation of biodiversity, are more likely to found at the level of population dynamics than in the realm of major environmental changes.

P3-74 BENOWITZ-FREDERICKS, ZM*; FIELD, K; SEYOUM, EK; HATCH, SA; KITAYSKY, AS; Bucknell Univ., Inst. Seabird Research & Conservation, Univ. Alaska Fairbanks; *zmbf001@bucknell.edu*

Transient elevations of corticosterone induce persistent changes in gene expression in growing kittiwakes

Exposure to elevated glucocorticoids during development can have long-term "programming" effects on phenotype, which are expected to be mediated by changes in gene expression. We tested the hypothesis that transient elevation of corticosterone in semi-precocial seabird chicks (Black-legged kittiwakes (*Rissa tridactyla*)) induces short-term changes in physiology and behavior, but longer-term effects on gene expression. From day 10 to day 16 post-hatch, free-living chicks from supplementally fed nests were fed (3x/day) with oil containing corticosterone (CORT) or oil only, or were non-handled controls (NHC). We measured baseline corticosterone levels, growth, and behavior. On day 25, we took pectoralis muscle biopsies, then generated a de novo transcriptome assembly and quantified gene expression. Oral corticosterone induced a short-term (detected 15 min but not 60 min after administration) elevation of baseline corticosterone, and did not affect corticosterone secretion post-treatment, development, or begging behavior of chicks. However, 9 days after treatments ended, chicks exhibited differential gene expression across treatments. A significant downregulation of immune-related genes in CORT chicks compared to NHC emerged as the most distinctive pattern (~60% of differentially expressed identified transcripts). Thus despite the apparent ability to tolerate acute elevations in glucocorticoids, young kittiwakes carry an imprint of such exposure that may affect their fitness. Alteration of immune function has long been recognized as a mechanism linking early stress with costs that manifest later in life. Here we identify some of the molecular mechanisms likely to underlie this programming.

P3-54 BENRABAA, S.A*; DAS, S.; MYKLES, D.L; Colorado State university; *saabmora@rams.colostate.edu*

Transcriptomics of Halloween and ecdysone-responsive gene expression in the crustacean molting gland

Molting is necessary for growth and development in all arthropods. Halloween genes are expressed in the molting gland (Y-organ or YO) and encode enzymes that catalyze the synthesis of ecdysteroid hormones that coordinate molting processes during the premolt stage. mTOR activity is required for YO activation and entry into premolt. Transcriptomics was used to quantify gene expression in *Gecarcinus lateralis* induced to molt by multiple limb autotomy (MLA) or eyestalk ablation (ESA) ± mTOR inhibitor rapamycin. For the MLA transcriptome, relative mRNA levels of Halloween genes were highest in intermolt and early premolt and then decreased during mid and late premolt to their lowest levels 10 days postmolt. ESA/Rapamycin transcriptome showed that Halloween genes and ecdysone-responsive genes levels were not significantly different from control groups and experiment groups except *HR4*, which showed a transient increase at 1-day post-ESA. Using qPCR, ESA decreased mRNA levels of Halloween genes, *Neverland* and *CYP18a1* at 3, 7, and 14 days post-ESA. Ecdysteroid receptor (EcR/RXR) binds active molting hormone, which induces serial activation of ecdysone-responsive genes. Insect gene sequences were used to identify contigs encoding *Broad Complex*, *E75*, *E74*, *HR4*, *HR3*, *forkhead box transcription factor*, and *Fushi tarazu factor-1*. The presence of *EcR/RXR* and ecdysone-responsive genes suggest that elevated ecdysteroid at the end of premolt and contributes to transcriptional inactivation in the repressed YO in postmolt.
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105-5 BENTZ, AB*; GEORGE, EM; ROSVALL, KA; Indiana University; *bentza@iu.edu*

Tissue-specific Gene Regulation Corresponds with Seasonal Plasticity in Female Testosterone and Aggression

Testosterone (T) is considered a key mediator of the trade-off between mating and parental effort, and as such, decreasing T as the breeding season progresses may be adaptive. Prior work has provided insight into the 'top-down' hypothalamic control of this seasonal plasticity; yet, emerging evidence suggests that peripheral mechanisms could also be important. Local regulation of T in peripheral tissues may be especially critical for females, as it would allow them to escape the costs of systemically elevated T while enabling T-mediated traits, like aggression. To begin testing this hypothesis, we measured aggression, plasma T, and peripheral gene expression across the breeding season in female tree swallows, a songbird with intense competition and T-mediated aggression. We focused on the gonad and liver for their role in T production and metabolism, respectively, and the pectoralis muscle for its role in aggression; i.e. because nest defense occurs in flight. We found that females had elevated T during early breeding, but T declined during incubation. Gene expression for ovarian steroidogenic enzymes and hepatic steroid-metabolizing enzymes also significantly declined. In contrast, aggressive response to a simulated intruder remained relatively robust until chick rearing, suggesting that T levels cannot fully explain variation in aggression. However, steroidogenesis and sensitivity to T in the pectoralis did not compensate for declining T, implying that enhanced T processing within this performance-related tissue does not facilitate aggression during incubation. Instead, other mechanisms, like enhanced neurosteroidogenesis or neural T sensitivity, could apply. Collectively, these data highlight important gene regulatory mechanisms that may underlie hormonal and behavioral plasticity in females.

110-5 BERGAMINI, RR*; GREENHALGH-ADAM, CD ; PROPPER, CR; Northern Arizona University; *Rex.Bergamini@nau.edu*

Site-specific Evaluation of Body Shape Response to Contamination in a Model Fish Species, Gambusia affinis

Endocrine disrupting chemicals (EDCs) are globally ubiquitous in aquatic systems. Chronic exposure to EDCs can disrupt endocrine functions and cause reproductive impairment in aquatic species. Western mosquitofish (*Gambusia affinis*) are an ideal model species for EDC exposure studies because they are distributed globally in surface waters, are sexually dimorphic and they exhibit specific shifts to secondary sex characteristics in response to xenoestrogens. Less is known about whether exposure affects other growth parameters and whether there are population differences in response to exposure. We hypothesized that fish body shape differs between populations and in response to exposure to estrogenic compounds. We collected *G. affinis* from each of two sites differing in their chemical profiles. Fish from each site were exposed in water from their collection sites to 1 nM ethynylestradiol (EE2) in 0.0002% ethanol (EtOH) or to vehicle. We used geometric morphometric analysis to define morphological landmarks of bodies and gonopodia and Procrustes superimposition to exhibit the variation between the four groups. Canonical variate analysis revealed significant site-related body shape differences between populations, and significant differences between treatment site animals in response to EE2 treatments, with greatest body changes in basal gonopodial width and centroid shape. These results suggest that a genetic bottleneck in fish collected from the spring may have resulted in selective forces that acted differentially on shape between the two populations and limited capacity to respond to xenobiotic exposure; these shifts in responsiveness to chemical pollution may affect reproductive success and have possible fitness outcomes that differ across populations.

P1-68 BERGER, AN*; LOHR, B; CLARK, CJ; Univ. of California, Riverside, Univ. of Maryland, Baltimore County; *aberg009@ucr.edu*

Hearing with small ears: Costa's Hummingbird (Calypte costae) Audition

Hummingbirds represent an interesting challenge for sensory processing- they have an extraordinarily small ear (1.3 mm basilar papilla length) and possess only ~1,000 sensory hair cells. As a comparison, the Zebra finch basilar papilla is 1.6 mm and contains ~3,600 hair cells. The specific consequences of hair cell number and basilar papilla length for hearing are not fully known. Some hummingbirds produce auditory signals above the frequency of greatest sensitivity for most birds. Costa's hummingbird *(Calypte costae)* vocalizations span 6 to 12 kHz with peak power at 10 kHz and they use these signals in displays, suggesting these sounds are audible. For comparison, most birds hear best from 1 to 5 kHz and have best sensitivity from 2 to 3 kHz. We predict that the Costa's hummingbird possesses frequency sensitivity that corresponds to the frequency range of their song, and an audiogram (graph of hearing threshold by frequency) that is shifted upward in frequency range when compared with the audiogram of other avian clades. We adapted a go/no-go psychoacoustic paradigm using pure tones and a two up, one down algorithm to measure auditory frequency sensitivity and intensity thresholds in order to assess the auditory abilities of Costa's Hummingbird. By studying hearing of a small-eared organism behaviorally, we will be able to gain more insight into how ear size and hair cell number might constrain hearing.

12-5 BERGMANN, PJ*; MORINAGA, G; SCHAPER, EG; IRSCHICK, DJ; SILER, CD; Clark University, UMass Amherst, Oklahoma University; *pbergmann@clarku.edu*
The evolution of snake-like body shape and its bearing on relationships between running and burrowing performance
The evolution of a snake-like body shape in terrestrial animals is thought to be an adaptation for burrowing, yet this remains largely untested. A corollary of this assumption is that one would expect a trade-off between surface running and burrowing performance. *Brachymeles* skinks include species ranging from pentadactyl and lizard-like to limbless and snake-like with intermediate forms, and phylogenetic evidence suggests that *Brachymeles* has evolutionary lost and then re-evolved limbs. This begs the question of why would a burrowing animal re-evolve limbs that were likely lost to enhance burrowing performance? One hypothesis is that re-evolved limbs may differ functionally from ancestral limbs and allow an animal to break the trade-off between surface running and burrowing. We tested this hypothesis using 12 species of *Brachymeles* and one outgroup taxon. We related the number of digits (a proxy for how snake-like a species is) to running and burrowing average and maximum velocity, and maximum acceleration. We also related each performance measure for running and burrowing to quantify performance relationships. Preliminary analyses suggested positive relationships between running and burrowing velocity measures, but a trade-off between running and burrowing acceleration. However, there were positive relationships between numbers of digits and both running and burrowing performance. Together, our results suggested that more lizard-like species were better at both modes of locomotion. In general, there was mixed evidence for a trade-off between the running and burrowing, and no relationship between the existence of such a trade-off and body shape.

23-3 BERK, SA*; BREUNER, CW; University of Montana; *sara.berk@umconnect.umt.edu*
Stress, Condition, and Sexual Selection in the Mountain Bluebird, Sialia currucoides
Traits that confer advantages during female choice or during male-male competition are said to be under sexual selection. While condition dependence of sexually selected traits is well supported in the literature, condition is difficult to define, leading to confusion in the field. Understanding how individual variation in response to challenge affects trait production is an important goal for the field of sexual selection. The endocrine system is an important mediator of condition dependence because hormones respond to environmental conditions to regulate internal response and resulting phenotype. The hormone corticosterone (CORT) is released by the adrenal glands in response to challenge to divert resources towards self-preservation and away from other purposes. Individuals vary in their stress responsiveness (the amount of CORT secreted in response to challenge), and the downstream response of other systems to CORT secretion. Using CORT physiology to study sexual selection allows for the exploration of dynamic changes in ornament production across environmental conditions. We studied the effects of food availability and corticosterone physiology on coloration and feather structure in the Mountain Bluebird. We brought 21 hatch year males into the lab and divided them into three treatment groups with n=7 birds each; food deprivation (80% food availability), corticosterone implant (Innovative Research of America), or CORT implant x food deprivation. Each bird grew one control set of feathers and one treatment set of feathers in a paired study design (n=7 birds). We evaluated ornamentation, feather structure, and stress physiology in response to the different treatments to determine how environmental and physiological conditions affect the various functions of feathers. We will discuss potential trade-offs between survival functions (feather structure), and internal and external conditions.

68-4 BERKE, SK*; DORGAN, KM; ROBERTSON, A; BELL, S; CAFFRAY, T; WELDIN, E; BUDAI, S; PARKER, R; GADEKEN, K; CLEMO, W; KELLER, EL; Siena College, Dauphin Island Sea Lab, Univ of South Florida; *sberke@siena.edu*
Long-Term Changes In Infaunal Communities Following The Deepwater Horizon Event.
Anthropogenic disturbances such as oil spills can present long-term challenges for affected communities. This is especially true in marine benthic environments, where the toxic components of crude oil can remain trapped in sediments for years or even decades. The 2010 Deepwater Horizon event was the largest marine oil spill in US history, sending nearly 500 million barrels of crude oil into the Northern Gulf of Mexico. We quantified benthic invertebrate communities in *Ruppia* beds versus unvegetated muds at oiled versus unoiled sites of the Chandeleur Islands. Shallow benthic communities are dynamic, with considerable seasonal and inter-annual variability. *A priori*, one might predict stochastic processes to obscure any fingerprint associated with oiling, especially many years after the event. Surprisingly, however, we find clear differences in abundance, taxonomic composition, and functional group at oiled sites. Subsurface deposit feeders appear to be more severely impacted, consistent with their intimate association with sediments. Characterizing the extent to which oiled habitats retain their functional capacity (i.e. biogeochemical cycling, productivity, advection, bioturbation, etc.) remains an important question.

S8-8 BERMINGAHM-MCDONOGH, Olivia; University of Washington; *oliviab@uw.edu*
Development and Regeneration in the Mammalian Inner Ear
Some of the first evidence for regeneration of hair cells came from studies of the lateral line organs of fish and amphibians. These organs consist of mechanosensitive neuromasts distributed along the body surface. In Uredels after amputation of the tail new neuromasts are generated in the lateral line organ at the stump and migrate to form new organs as the tail regenerates (Stone, 1937). Studies by Jones and Corwin demonstrated that a low level of ongoing proliferation is dramatically up regulated after hair cells in the lateral line are destroyed by a laser (Jones and Corwin, 1993, 1996). Direct time-lapse recordings demonstrated that the regenerated hair cells rose from support cells (Jones and Corwin, 1993). A similar increase in mitotic proliferation of support cells occurs in fish after various types of ototoxic damage (Hernandez et al., 2007; Ma et al., 2008 and Williams and Holder, 2000), and the proliferating cells go on to replace the hair cells within 48hours of the insult. Similarly birds can replace hair cells in their inner ear sensory organs. In birds there is ongoing turnover in the utricle throughout life that can be up regulated in response to ototoxic injury. The situation in the auditory organ the basilar papilla in birds is different in that there is no ongoing replacement yet after ototoxic damage that destroys hair cells there is a robust proliferative response. Support cells re-enter the cell cycle within 16hours and new hair cells appear within 2-3 days. This replacement of hair cells restores function. In this presentation I will give an overview on recent finding regarding regeneration in mammalian inner ears. I will also describe some of our own studies on development of the sensory organs in the inner ear of the mouse and on our attempts to encourage regeneration.

74-6 BERNARDS, M.A.; SCHORNO, S; MCKENZIE, E; WINEGARD, TW; OKE, I; PLACHETZKI, D; FUDGE, DS*; Univ. of Guelph, Univ. of New Hampshire, Chapman Univ.; *fudge@chapman.edu*

Unraveling skein deployment in hagfish slime: Insights from transcriptomics and in vitro assays

Hagfishes defend themselves from fish predators by producing defensive slime consisting of mucous and thread components that interact synergistically with seawater to pose a suffocation risk to their attackers. Deployment of the slime occurs in a fraction of a second and involves hydration of mucous vesicles as well as unraveling of the threads from their elaborately coiled state to their full length of approximately 150 mm. Previous work has shown that unraveling of coiled threads (or "skeins") in Atlantic hagfish requires vigorous mixing with seawater as well as the presence of mucus, whereas skeins from Pacific hagfish tend to unravel spontaneously in seawater. Here we explored the mechanisms that underlie these different unraveling modes, and focused on the molecules that make up the skein glue, a material that must be disrupted for unraveling to proceed. We found evidence that *M. glutinosa* possesses skein glue, and that it is less soluble in seawater than *E. stoutii* glue. Using SDS-PAGE, mass spectrometry, and transcriptomics, we identified several putative skein glue proteins that are expressed in the slime glands of both species. We identified 14 protein sequences that are likely glue components, with three of them being highly charged acidic proteins that lack homology with any other proteins. Although the ecological significance of the two modes of skein unraveling described here are unknown, they may reflect differences in predation pressures, with selection for faster skein unraveling in the *Eptatretus* lineage leading to more soluble glue.

P1-187 BERTHELEMY, NJ; Weber State University, Ogden; *nberthelemy@weber.edu*

Effects of Glyphosate and Roundup on the brine shrimp Artemia franciscana

Introduction: The herbicide Roundup and its active ingredient, Glyphosate, used for weed control, end up in water where they affects life, including, the brine shrimp *Artemia franciscana*, from the Great Salt Lake. The goals of this project were to understandthese herbicides a) short term effect, b) their long term effect and c) the shrimp stress response. Materials and Methods: In the short term exposure (a), *Artemia* larvae were exposed for 48 hours to Glyphosate and Roundup in concentration ranging from 10^{-2} to 10^{-7} and 0 (control, Co) g/l. In the long term exposure (b) larvae were raised in the above solutions in 0, 10^{-8}, 10^{-7}, 10^{-6}, 10^{-5}, 10^{-4} 10^{-3}g/l Glyphosate concentration. Survival, growth, maturation and fertility rates were recorded. For stress monitoring (c), the up-regulation of stress proteins hsp22, 70 and 90 was assessed. Results: a) All larvae and adult were killed by all Glyphosate solutions at 10^{-2} g/l concentration. Mortality rates at 10^{-3} g/l and below varied with the type of solution containing the Glyphosate. Shrimp placed in 10^{-4} g/l or lower concentrations survived as well as the control. b) Shrimp could not survive to maturation in Glyphosate/Roundup at 10^{-3} g/l or higher. Most shrimp matured in about 25 days after hatching, with no significant difference with the control. Fertility (or the number of eggs per brood) was the most affected. All shrimp exposed to any type of Glyphosate produced significantly less offspring than the control (60 or less in the exposed shrimp compared to 78 eggs/brood in the controls). In addition, an unusual number of aborted eggs was noticed. c- Heat-shock proteins 70 expression increased with higher Glyphosate exposure, suggesting upregulation. Conclusion: The most noticeable effect of Glyphosate is on fertility and potentially on embryonic development.

P1-246 BEYL, HE*; BREUNER, CW; University of Montana; *hannah.beyl@umconnect.umt.edu*

Corticosteroid-binding globulin: Evaluation of methods and estimation of free CORT

Life history theory posits an intrinsic trade-off between survival and reproduction but the proximate mechanisms regulating these tradeoffs are not well understood. The glucocorticoid-driven stress response is thought to mediate this tradeoff. Corticosteroid-binding globulin (CBG) likely regulates corticosterone's (CORT) access to tissue. CBG varies by species, season, population, life history sub-stage, sex and changes with acute and chronic stress. However, there is still disagreement as to both CBGs role in stress reactivity, as well as the best methods for measuring plasma CBG. Charcoal and vacuum filtration are the main techniques for measuring CBG. I focus on the vacuum filtration method and address the critique of temperature's effect on the disassociation constant of CBG. I ran CBG assays at two different temperatures (21˚C and 41˚C) to understand the differences in estimates of the dissociation constant (K_d). Using house sparrow plasma, I demonstrate a temperature-sensitivity of the CBG assay and suggest that we are under-estimating the amount of free CORT across several species birds, and likely across vertebrates. An understanding of CBG is essential to studies involving stress and behavior.

P2-77 BHARDWAJ, E*; BERG, O; MÜLLER, UK; BUSHOVEN, JT; CSU Fresno; *eshanb@mail.fresnostate.edu*

Can metabolite profiling help explore what causes the small genome in bladderwort?

Bladderworts are carnivorous plants that trap microscopic organisms in under-water traps. Bladderworts are remarkable among plants in two ways: they have one of the smallest nuclear haploid genomes (88 Mbp) among known angiosperms, and they are the fastest predators with traps that ingest prey within less than a millisecond. The mechanisms behind re-setting of the suction traps is energetically intensive, and known to generate Reactive Oxygen Species (ROS), which puts these plants under continuous oxidative stress. Whole genome sequencing of bladderwort has revealed that all parts of the plant express ROS-detoxification and DNA-repair enzyme genes, which supports the hypothesis that the mutagenic action of high ROS activity increases nucleotide substitution rates. The small genome might be explained by the prohibitive cost of DNA repair. In this project, we want to explore whether the trap resetting mechanism is indeed responsible for raising ROS levels in bladderworts. Profiling of plant metabolites using Nuclear Magnetic Resonance (NMR) spectroscopy has already been used to identify ROS activity in Arabidopsis via detection of stress-related compounds. The usefulness of this approach for studying bladderworts however still needs to be tested. We developed a protocol to vary the rate of trap firing and resetting to explore whether increasing trap activity modulates ROS levels. Our protocol uses two different approaches to study the effect of trap resetting activity on ROS production. First, trap age has a strong effect on spontaneous trigger frequency, causing young traps to reset more often than old traps. Second, mechanical stimulation (flow) and changing the water ionic content affects firing rates. We are currently exploring whether those firing rate changes affect ROS levels in the plant.

60-5 BHAVE, RS*; REEDY, AMR; SEEARS, HA; KAHRL, AF; COX, RM; Univ. of Virginia, Stockholm University; *rsb7bz@virginia.edu*

Do back-pattern morphs in female brown anoles differ in morphology, behavior, and natural selection?

While polymorphisms within males have been studied extensively, relatively less attention has been paid to polymorphisms specific to females. In this study, we focused on a heritable back-pattern polymorphism in females of the brown anole lizard, *Anolis sagrei*. In most brown anole populations, females have a distinctive back pattern comprised of a longitudinal bar, diamonds, or diamond-bars. However, in some populations, females can also have a chevron back pattern similar to that of males. To explore the adaptive significance of this sex-limited polymorphism, we used data from an ongoing mark-recapture study of an island population of brown anoles in Florida (n ~ 1000 females across 2 years) to test for differences in morphology, survival, and natural selection between male-like and female-like morphs. We found that morphs did not differ in morphology (body size, limb length, head dimensions, dewlap size), or in the strength and direction of natural selection on these phenotypes. Although male-like females had lower probability of survival than female-like morphs as juveniles, this pattern was inconsistent across life stages and years. We also observed the behavior of these morphs in the wild, in response to staged territorial intrusions by females of the same and opposite morph. Although the two morphs did not differ in their probability of attacking intruders, they tended to display more towards intruding females with the same back pattern, suggesting that individuals may perceive and respond to differences in back patterns. Future studies will focus on quantifying the reproductive success of each morph.

P3-241 BIEDAK, N*; BAKER, JA; FOSTER, SA; Clark University; *nbiedak@clarku.edu*

Quantification of Phenotypic Variation in Newfoundland Populations of Threespine Stickleback

Phenotypic variation in morphology has been well characterized in Alaskan and British Columbian populations of threespine stickleback, with studies demonstrating that the variation is extensive in a wide variety of anti-predator traits and body shape. In contrast, the limited published studies of stickleback in eastern North America suggest that there is relatively little among-population phenotypic variation in anti-predatory armor and body shape. Recent samples obtained from 30 populations of stickleback in Newfoundland, from a wide array of habitats that vary in biotic and abiotic components, indicate that the earlier suggestion of relatively limited phenotypic diversity may need to be reevaluated. Using geomorphic morphometrics plus more traditional measures of specific body parts (for body shape), and measurements and counts of armor features (for anti-predator aspects), I will quantify the degree of variation both within an across populations. Using summary metrics, I will then compare the variability of Newfoundland populations to that of Alaskan populations, to more rigorously test the original suggestion of more limited variation. Data acquisition is currently underway for this comparison.

121-1 BIGMAN, JS*; WEGNER, NC; DULVY, NK; Simon Fraser University, Southwest Fisheries Science Center, National Marine Fisheries Service; *jbigman@sfu.ca*

Vertebrate-wide scaling of metabolic rate and respiratory surface area

The amount of energy devoted to survival, growth, and reproduction governs the speed of life, or the position of a species on a continuum of slow to fast life histories. Energy availability is governed by metabolic rate, which is the rate of resource uptake and allocation. Thus, metabolic rate likely shapes life histories, and environmental factors act to shape metabolic rate. Yet, few studies have explored the relationships between metabolic rate, environmental factors, and life history. As metabolic rate is most commonly assessed by measuring oxygen consumption in the laboratory, this often precludes collecting metabolic data for large-bodied, aquatic organisms. Previous work has suggested that metabolic rate and respiratory morphology are linked, and that the surface area of the lungs or gills can act as a proxy for metabolic rate. To date, the relationship between metabolic rate and respiratory surface area has not been explicitly explored. Here, we analyze the utility of using respiratory surface area as a proxy for metabolic rate using the theoretical framework of the Metabolic Theory of Ecology. We first test the predictions of the Metabolic Theory of Ecology by examining the body-mass scaling of metabolic rate in vertebrates. Then, we compare the body-mass scaling of respiratory surface area in vertebrates to that of the Metabolic Theory of Ecology predictions. We finally assess how respiratory surface area fits into the Metabolic Theory of Ecology framework. Our results show that the allometries of metabolic rate and respiratory surface area for our vertebrate dataset scale similarly, and that including respiratory surface area in the Metabolic Theory of Ecology framework accounts for a significant portion of the remaining variation.

37-2 BIRK, MA*; SEIBEL, BA; University of South Florida; *matthewabirk@gmail.com*

Squids Do Not Breathe Through Their Skin

In 1990, a hypothesis was put forth that squids obtain a fairly large portion (as much as 50+%) of their oxygen via simple diffusion across the skin rather than across the gills. This was proposed initially to explain the paradox of how squids sustain oxygen delivery to their tissues despite an extremely high Haldane coefficient. Although this idea has good theoretical support and has been generally regarded as valid for the two decades since, no empirical examinations have been conducted to assess the validity of this hypothesis. In this study, we examined this claim via manipulative experiments on two squid species, *Doryteuthis pealeii* and *Lolliguncula brevis*, by mechanically separating the oxygen consumption through the gill and skin of an intact animal using respirometry in a divided chamber. We found that this hypothesis, although enjoying good circumstantial evidence, was not supported by empirical examination. In contrast, we estimate that squids at rest obtain no more than 10% of their O_2 cutaneously, with the majority of O_2 entering via the traditional branchial pathway. We furthermore re-examine the theoretical evidence that has supported the cutaneous respiration hypothesis and discuss its implications in a non-cutaneous context.

133-3 BIRK, MA*; MCLEAN, EL; SEIBEL, BA; University of South Florida, University of Rhode Island; *matthewabirk@gmail.com*

Hypoxia Tolerance Unaffected by Ocean Acidification in Active Squids

There has been concern that ocean acidification may limit the performance of squids due to their exceptionally high oxygen demand and the potential for reduced oxygen supply in acidified waters due to their highly pH-sensitive blood pigments. The critical oxygen partial pressure, P_{crit}, is a commonly reported index of hypoxia tolerance. Defined as the PO_2 at which oxygen supply matches demand, P_{crit} should serve as a sensitive indicator of the impact of CO_2 on cardiorespiratory physiology. In this study, we assessed the effects of CO_2 (40 to 500 Pa) on the metabolic rate and P_{crit} of two active squid species: *Dosidicus gigas* and *Doryteuthis pealeii*. We found that *D. gigas* had a P_{crit} 2.2 kPa lower than *D. pealeii* despite similar metabolic rates. The lower P_{crit} in *D. gigas* is consistent with adaptations for its oxygen minimum zone (OMZ) habitat, such as high affinity respiratory protein and enhanced gill size. Carbon dioxide had no effect on metabolic rate or hypoxia tolerance in either species. Furthermore, considering oxygen transport parameters (e.g. Bohr coefficient, blood P_{50}) and blood PCO_2 values, we estimated that an increase in seawater PCO_2 to 100 Pa (1000 µatm/ppmv) would result in a maximum change in P_{crit} of 0.6 kPa in the absence of active extracellular pH compensation. Such a change is unlikely given the capacity for acid-base regulation in many cephalopods. Moreover, this estimated change is within the 95% CI of the P_{crit} measurement reported here. Thus, it is not surprising that we found no significant effect of CO_2 on P_{crit}. Squid blood-O_2 binding is expected to be more sensitive to ocean acidification than in any other marine animal. Therefore, the lack of effect in squids suggests that ocean acidification is unlikely to have a limiting effect on blood-O_2 binding in any organism.

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What do nematode swimming gaits optimize?

Work on a variety of organisms suggests that at moderate to high speeds animals can select their gaits for many goals, optimizing the cost of transport, speed, or chances of avoiding injury. Here we examine the motion of the nematode *Caenorhabditis elegans* using a newly developed geometric gait optimization tool. For animals operating in friction dominated regimes, such as viscous swimming, the locomotion is governed by a "connection" as used in the theory of geometric mechanics. By combining tools of kinematic phase analysis with those of geometric mechanics, our gait optimization tool models the connection governing a gait, allowing the computer to climb the gradient of goal functions such as the cost of transport. Using swimming data kindly provided by the Penn Complex Fluids Lab, we validated a Purcell swimming model and discovered that its moment equation contributed little (< 1%) to the motion per cycle. Using a simplified model absent the moment equation, we optimized gaits for extremal motion (maximum displacement per cycle) and for cost of transport, using the animals' observed motion as the initial condition. We classified the resulting gaits by the mean time derivative of absolute curvature, and by the mean power. This gave 4.2+/-.27 [rad/mms] and 74.+/-12. [fW] for the animals, falling close to the 5.6 [rad/mms] and 15. [fW] of the optimal cost of transport gait, and further away from the 11. [rad/mms] and 270. [fW] of the extremal gait. We conclude that these nematodes motions are consistent with cost of transport having a significant weight in their choice of gait. Although unused here, our tool is model free, and can model the connection from motion captured gait data. This work may further illuminate how animals select their locomotor patterns and allow hypotheses of optimality to be rapidly tested.

P3-207 BITTNER, NKJ*; NACHMAN, MW; Univ. of California, Berkeley; *nbittner@berkeley.edu*

Desert adaptation and water consumption in the house mouse Mus musculus

Life in a desert environment imposes harsh selection pressures on those who inhabit it. Modifications to decrease water loss, increase thermoregulatory capacity, and otherwise thrive in these environments have been well documented in many desert specialists, but how do these modifications extend to generalists recently introduced to a desert environment? House mice, *Mus musculus domesticus*, have been present in the Americas since western colonization and have been shown to exhibit variation associated with environmental differences. Of particular interest is the way in which populations of mice living in the Sonoran desert have responded to desert conditions over this short time scale. Here, we show mice living in these populations show decreased need or preference for water compared with populations found throughout other biomes in the Americas. We subsequently search for genomic signals of selection associated with desert living in these populations. We demonstrate that Sonoran desert house mice exhibit unique adaptations associated with the decreased water access of their desert environment.

S9-8 BIZE, Pierre; University of Aberdeen; *pierre.bize@abdn.ac.uk*

Effects of the Mitochondrial and Nuclear Genomes on Adaptation to the Environment and Phenotype of Mammals

A key adaptation of mammals to their environment is their ability to maintain a constant high body temperature, even at rest, under a wide range of conditions (i.e. endothermy). In cold climates, this is achieved by an adaptive production of endogenous heat, known as nonshivering thermogenesis (NST), in the brown adipose tissue (BAT). This organ, unique to mammals, contains a very high density of mitochondria, and thus the correct functioning of the BAT ultimately relies on the correct functioning of its mitochondria. Remarkably, because mitochondria enclose proteins encoded both in the maternally inherited mitochondrial genome and in the biparentally inherited nuclear genome, one hypothesis is that both genomes and their interaction may shape mammalian NST and other phenotypic traits such as body mass. By housing under similar standardised conditions wild-derived common voles from two distinct mitochondrial lineages (Western and Central), we show that Western voles have greater NST capacity and were heavier than Central voles. By introgressing these two lineages over more than 10 generations, we then experimentally tested the contribution of the nuclear and mitochondrial genomes. This shows that BAT weight and NST capacity were significantly influenced by the nuclear and mitochondrial genomes, respectively, and that whole animal body weight was influenced by mito-nuclear interaction. These findings turn new light on the importance of the mitochondrial and nuclear genomes in shaping the phenotype and building adaptation to the environment in mammals.

58-5 BLACKBURN, DG; Trinity College, Hartford CT; *daniel.blackburn@trincoll.edu*

Yolk Cellularization and Amniote Egg Evolution

Evolution of the amniotic (terrestrial) egg required a new form of cleavage and a new mechanism for processing of yolk for development. Reptiles are widely assumed to process yolk as do birds - implying a developmental mechanism that dates back ~340 million years. However, recent work in our laboratory reveals that snakes, lizards, and turtles cellularize yolk very differently than birds. In the avian pattern, a vascularized yolk sac surrounds the liquid yolk, and cells that line it progressively phagocytose and digest the yolk material. In contrast, in the reptiles that we have studied, endodermal cells proliferate and take up yolk droplets, forming large clumps that protrude into the yolk sac cavity. Upon vascularization, these yolk-filled cells become arranged in a monolayer around each blood vessel. As a result, the yolk sac cavity becomes filled with a compact mass of spaghetti-like strands of yolk- coated blood vessels. Yolk nutrients in non-avian reptiles are thereby digested and delivered efficiently into the blood stream for embryonic use. If the developmental pattern of squamates and turtles is ancestral for amniotes, the clade leading to birds must have abandoned it in favor of a very different pattern. Consequently, the history of the amniote egg is more complicated than is commonly assumed, and must be revised to recognize dual mechanisms for yolk processing among sauropsids.

2-2 BLACKBURN, DC; BLACKBURN, David; University of Florida; *dblackburn@flmnh.ufl.edu*

3D Anatomical Data for All: The oVert Thematic Collection Network

The oVert (openVertebrate) Thematic Collection Network (TCN) will generate and serve high-resolution digital three-dimensional data for internal anatomy across vertebrate diversity. At a network of digitization centers across the US, we will CT-scan >20,000 fluid-preserved specimens representing >80% of the living genera of vertebrates. This will also provide broad coverage for exploration and research on all major groups of vertebrates. We will generate contrast-enhanced scans to reveal soft tissues and organs for a majority of the living vertebrate families. This collection of digital imagery and three-dimensional volumes will be open for exploration, download, and use to address questions related to the discovery of new species, documenting patterns of anatomical diversity and growth, and testing hypotheses of function and evolution. Our network of leading US vertebrate collections will develop best practices and guidelines for high-throughput CT-scanning, including efficient workflows, preferred resolutions, and archival formats that optimize the variety of downstream applications. We will also upgrade the interface and functionality of MorphoSource, an on-line data depository for 3D data of biological specimens, improving its capacity to explore media, capture standardized metadata, ingest legacy data from previous and existing projects, supply media information to data aggregators including iDigBio, and engage educators and students. To drive the use of these digital specimens by K12 STEM educators, we will conduct teacher-driven workshops that generate freely available lesson plans focused on specific science standards that are based on digital and printed 3D models of specimens in US museum collections.

P2-199 BLOB, RW*; WILSON, JA; MARSICANO, CA; PANKO, LJ; SMITH, RMH; Clemson Univ., Univ. of Michigan, CONICET-Univ. de Buenos Aires, Northwestern Univ., Univ. Witwatersrand, Iziko South African Museum; *rblob@clemson.edu*

Locomotor Kinematics of Fossil Dinocephalian Therapsids Reconstructed from Three-dimensional Footprint Morphology

The Gansfontein paleosurface (Mid-Permian, South Africa) preserves several footprints, including a trackway attributed to a single dinocephalian (a lineage of non-mammalian therapsids). In contrast to the straight digital axis indicated by articulated hands and feet of dinocephalians, digit impressions in this trackway are curved, with tips directed toward the trackway midline. To evaluate how such curved-digit prints were produced, we constructed contour maps to measure how the depth of an impression varied within individual prints. We poured milk into prints in successive increments of 2 mm in height, and traced the perimeters of filled areas on translucent paper taped to the paleosurface. Contours show features consistent with outward rotation of the hand and foot during stance. For example, impressions of digit I are shallow, but impressions of digit V are deep. Lateral edges of digit IV impressions are also steeper than medial edges. Thus, depth asymmetry between or within digits shows deeper or steeper lateral edges, consistent with outward foot rotation. Finally, distal tips of digit impressions are among the shallowest portions of prints; however, local 'overdeepened' depressions are present several centimeters from distal digit tips, indicating that the toes rotated out from their initial point of placement prior to lifting of the foot off the ground. Despite narrow spacing between left and right prints, the presence of foot rotation during stance supports osteological evidence that dinocephalians used sprawling, rather than parasagittal limb posture. Close spacing of prints likely resulted from lateral bending of the body and significant cranio-caudal limb excursion, rather than adduction of the limbs under the body.

70-7 BLOCK, B.A. *; GLEISS, A.; CROMIE, M.; DIMITROV, M.; SCHALLERT, R.; WILSON, S.; DALE, J.; Stanford U.; *bblock@stanford.edu*

Geared for the Open Ocean: The Biomechanics of Swimming in Bluefin Tunas

Bluefin tuna are trans-oceanic migrators known for their efficient locomotion. They possess a range of physiological and mechanical adaptations geared towards high-performance swimming. We equipped Atlantic bluefin tuna with motion-sensitive tags and video cameras to quantify the gaits and kinematics of wild fish. Our data reveal significant variety in tuna swimming kinematics, ranging from continuous locomotion to two types of intermittent locomotion. The tuna carrying these tags sustained swimming speeds in excess of 3 m s-1 (1.2 body lengths s-1), while beating their tail at a frequency of 0.9 Hz. Some descents were entirely composed of passive glides, with slower descents featuring more gliding, while ascents were primarily composed of active tail-beats. While the locomotive advantages of the tuna's fusiform body shape and endothermy are well established, the contributions of their unique musculoskeletal geometry are less clear. The aerobic red muscle that powers swimming is positioned medially, with more of the musculature positioned anteriorly than posteriorly. The red muscle is connected to the spine through a network of long tendons and bony ribs. We provide new musculoskeletal architecture measurements of tuna red muscle, tendon, ribs, and spine, enabled by a novel dissection approach. We developed a two-dimensional musculoskeletal model and kinematic simulation of sustained swimming to assess effects of tendon stretch on muscle fiber dynamics. We hypothesize that stretch of the elastic tendons allows the muscle fibers to be activated at their optimal lengths and lower shortening velocities. Quantitative understanding of the tuna biomechanics could inform the design of bioinspired vehicles. Supported by ONR.

P2-166 BLUM, KP; LAMOTTE D'INCAMPS, B; ZYTNICKI, D; TING, LH*; Emory / Georgia Tech, Université Paris Descartes; *lting@emory.edu*

Force Encoding in Muscle Spindles during Stretch of Passive Muscle

Muscle spindle proprioceptive receptors play a primary role in encoding the effects of external mechanical perturbations to the body. During externally-imposed stretches of passive muscles, instantaneous firing rates (IFRs) of muscle spindles are associated with stretch length and velocity. However, there are history-dependent transients of muscle spindle firing that are not uniquely related to muscle length and velocity, nor reproduced by current muscle spindle models. These include acceleration-dependent initial bursts, increased dynamic response to stretch velocity if a muscle has been isometric, and rate relaxation, i.e., a decrease in tonic IFR when a muscle is held at a constant length after being stretched. We collected muscle spindle spike trains across a variety of muscle stretch kinematics, systematically altering stretch length, velocity, and acceleration. We show that muscle spindle primary afferents in passive muscle fire in direct relationship to muscle force-related variables, rather than length-related variables. Linear combinations of whole muscle-tendon force and the first time derivative of force (dF/dt) predict the entire time course of transient, history-dependent muscle spindle IFRs during muscle lengthening in passive muscle. Similar to acceleration scaling found previously in sensorimotor postural responses to perturbations, initial burst amplitude scaled equally well to initial stretch acceleration or dF/dt, though, later transients were only described by dF/dt. The transient increase in dF/dt at the onset of lengthening reflects muscle short-range stiffness due to cross-bridge dynamics, which play a critical role in history-dependent muscle spindle IFRs in passive muscle lengthening conditions relevant to the detection and sensorimotor response to mechanical perturbations to the body.

P1-100 BOAG, TH*; ELDER, LE; HULL, PM; SOMERO, GN; SPERLING, EA; Department of Geological Sciences, Stanford University, Department of Geology & Geophysics, Yale University, Department of Biology, Stanford University; *tomboag@stanford.edu*

Bidirectional temperature effects on aerobic scope limits the range-shift capacity of marine fauna

Two of the many consequences of climate change are the warming and subsequent deoxygenation of Earth's oceans. This poses a major ecophysiological threat to marine ectotherms, where increasing temperature is traditionally considered to limit aerobic scope (ability to elevate respiration above a basal level) unidirectionally by raising metabolic rates beyond the capacity of the animal to take up adequate oxygen from its environment. In response, range-shifts within affected species to cooler, more oxygenated waters at greater depths or higher latitudes is often considered a resultant physiological strategy. However, the influence of temperature on aerobic scope in marine invertebrates is not well known. Using standard respirometry protocols applied to intertidal invertebrates from the Pacific, Atlantic, and Gulf of Mexico basins, we examined oxygen- and capacity-limited thermal tolerance in multiple taxa across two separate phyla both with (Annelida; triploblastic) and without (Cnidaria; diploblastic) circulatory systems. We find that absolute oxygen tolerance (measured as the onset of anaerobiosis, or critical partial pressure) decreases at temperatures both above and below distinct taxon-specific optima. These data suggest the loss of ventilatory capacity at temperatures colder than a species-specific optimum may inhibit ectotherms' ability to withstand environmental hypoxia. This in turn impacts strategies such as migration, which will be both more limited and subject to acclimatization capacity than previously considered.

112-6 BOAG, TH*; ELDER, LE; HULL, PM; SPERLING, EA; Department of Geological Sciences, Stanford University, Department of Geology and Geophysics, Yale University; *tomboag@stanford.edu*

Oxygen, temperature, and the cold cradle of animal evolution: a paleophysiological perspective on the Ediacaran fossil record

The Ediacaran Period records the earliest evolution of complex macroscopic life, characterized by benthic eukaryotes, sponges, cnidarians, and simplistic burrows made by mobile bilaterians. These fossils appear concomitant with geochemical evidence for an increase in atmospheric O2 and oceans that were perhaps significantly warmer than modern. Interestingly, these 'Ediacara biota' occur globally as early as 571 Ma in deep-water, aphotic slope facies, but remain absent in shelf environments until 560-555 Ma. The Ediacaran record therefore displays a puzzling 15 Myr period when large complex eukaryotes arose and flourished in bathyal settings, but did not inhabit shallow-water environments. To explore this apparent evolutionary pattern, the O2 and capacity limited thermal tolerance of marine intertidal invertebrates with bodyplans functionally analogous to Ediacaran organisms was measured to better understand the synergistic effect of temperature in low O2 partial pressure (PO2) oceans. Across all measured polychaete and cnidarian taxa, the onset of anaerobiosis, measured as the critical PO2, was found to vary systematically with temperature above and below taxon-specific optima. These data suggest that the aerobic capacity of early macroscopic organisms would have required habitats with relatively stable temperatures. In other words, life may have been excluded from shallow waters in low-O2 redox landscapes due to seasonal and perhaps even diurnal temperature fluctuations. Ultimately, the evolution of earliest animals in isothermal deep-marine refugia may represent a physiological consequence of Ediacaran oceans characterized by low and dynamic PO2.

P2-57 BOATENG, AA*; YEUNG, NW; KIM, JR; HAYES, KA; Howard University, Washington, DC, Bernice Pauahi Bishop Museum, Honolulu, HI; *boateng.asimah@gmail.com*

Intermediate Hosts of Angiostrongylus cantonensis in Invasive Hawaiian Land Snails from the Island of Maui

Angiostrongylus cantonensis, the Rat Lungworm (RLW), is a parasitic nematode and the cause of angiostrongyliasis, an emerging infectious disease impacting public health globally. The geographic range of RLW continues to expand with its intermediate hosts, snails. Humans may be infected after consuming undercooked or raw snails carrying the RLW, and recent outbreaks of the disease in Hawaii have refocused attention on controlling the parasites spread. While the definitive hosts (rats) are widespread globally, the intermediate snail hosts continue to spread and establish, and may be key to controlling the disease. Understanding of snail taxonomy, distributions, and infection status are critical to developing effective management and outreach plans. To provide this information, we surveyed 73 sites and collected 2,193 non-native snails across the island of Maui, which had 15 cases of angiostrongyliasis in 2017. Thirty snail species were identified, and 212 from 32 sites were tested for RLW using a PCR based assay. Only 14 snails from six species at eight sites were positive for RLW. Previous studies reported the highest incidence of infection in Parmarion martensi populations on the islands of Oahu and Hawaii. This species was only recently recorded on Maui and is associated with reported angiostrongyliasis cases there, highlighting the need for ongoing monitoring of invasives to avoid the continued spread of RLW hosts. Results from this and future work will help increase public awareness and improve quarantine efforts for invasive species, and aid state and local agencies in the development and implementation of RLW management plans.

P3-59 BOCKUS, AB*; LABRECK, CJ; CAMBERG, JL; SEIBEL, BA; Louisiana Universities Marine Consortium, Chauvin, Univ. of Rhode Island, Kingston, Univ. of South Florida, St. Petersburg; *abockus@lumcon.edu*

Exploring the use of trimethylamine oxide as an alternative to heat shock protein 70 with acute elevated temperature in elasmobranchs

Trimethylamine oxide (TMAO) and heat shock protein 70 (HSP70) are intracellular components directly involved in the thermal stress response, both protecting protein function at elevated temperatures. This study examines the effect of increasing temperature on the simultaneous regulation of these constituents *in vivo*. Using two elasmobranch species with innately high levels of TMAO, we address whether there is coordination between TMAO and HSP70 during a 6°C increase in temperature over 72 hours. The spiny dogfish, *Squalus acanthias*, a species with no endogenous synthetic capacity for TMAO, was compared to the smoothhound, *Mustelus canis*, a synthesizing species. There was no difference in plasma or tissue TMAO content between individuals held at control or elevated temperature in either species. These data suggest that, at the level of the whole organism, elasmobranchs do not rely on this molecule to combat acute thermal fluctuations. HSP70 increased nearly three-fold with increasing temperature in the white muscle of *S. acanthias* but not *M. canis*. The elevated HSP70 in *S. acanthias* demonstrates that the characteristically high TMAO content in this species does not confer sufficient protection to offset the denaturing effects of elevated temperature. The lack of HSP70 accumulation in *M. canis* was surprising and may be explained by species-specific differences in thermal range and tolerance, also discussed here. Our findings are in contrast to previous studies conducted with elasmobranch cells in vitro that show accumulation of TMAO with thermal stress and subsequent suppression of the HSP70 response.

11-5 BODENSTEINER, B/L*; WARNER, D/A; IVERSON, J/B; MILNE-ZELMAN, C/L; MITCHELL, T/S; REFSNIDER, J/M; VOVES, K/C; JANZEN, F/J; Virginia Tech, Auburn University, Earlham College, Aurora University, University of Toledo, Iowa State University; *bodenbro@vt.edu*

Examining the role of macrogeographic variables in predicting key phenotypes in a widespread reptile: lessons from the lab and field

Species with large geographic ranges experience considerable variation in climate, and are thus key reservoirs of ecological, phenotypic, and genetic diversity. Such organisms are excellent systems for revealing the process of local adaptation and divergence. Maternal effects, such as nest-site choice, may impact offspring phenotypes and survival, and thus have the potential to mitigate the effects of divergent climatic conditions. Understanding how variation in key traits are spatiotemporally distributed across species' ranges will improve our predictions of current and future adaptation to climate change. We examined natural nesting areas in six populations of painted turtles (*Chrysemys picta*), spanning ~15° latitude, and quantified spatial and temporal variation in nest microhabitat characteristics across the nesting season. At all sites females nested non-randomly, selecting nest sites with a warmer nesting environment when compared to the area available for nesting in a given location. Natural nest microhabitats differed among locations, but did not predictably vary with latitude during development for a given location. The distribution of our thermal data suggests that females choose nest sites that buffer against developmental minimum temperatures, rather than maximum environmental temperatures. Thus, nest-site choice may be unlikely to compensate for the novel stressor of rapidly increasing ambient temperatures in these populations. Elucidating how organisms with temperature-sensitive traits persist in these vastly different environments is key to predicting how they may respond to rapidly changing thermal conditions predicted under climate change models.

P2-182 BOERMA, DB*; BREUER, KB; SWARTZ, SM; Brown University; *david_boerma@brown.edu*

Both Symmetrical and Not: Complex Wingbeat Kinematics Enable Rapid Recovery from Aerial Stumbles in Bats

All flying animals move through complex environments. Air turbulence, crowded migrations, cluttered forests, and other factors challenge locomotion in nature and require animals to effect rapid neuromuscular responses that maintain or restore control when navigating unsteady conditions. By studying how bats perform recovery maneuvers following perturbations, we stand to gain insight into how they maintain control when challenged by unexpected flight disruptions and therefore make steps toward a broader understanding of flight in complex, naturalistic conditions. Here, we studied how bats alter wingbeat kinematics to recover from perturbations that impart rapid changes in orientation. We developed an experimental system in which we administered well-defined gusts to steadily flying *Carollia perspicillata*, which induced behavior that we term "aerial stumbles", and we determined which wing movements they employ to recover. Perturbations to one wing induced body roll, and bats recovered within one wingbeat (~0.1 s) by employing left-right asymmetry in wing extension, but not in humeral elevation and depression (flapping angle). During recovery, bats selectively extended one wing using a combination of humeral protraction, elbow extension, and digit abduction. This period of asymmetrical extension was concurrent with periods of sustained body roll that resulted in recovery. The muscle groups that drive wing extension/retraction in bats are distinct from those that control wing elevation/depression. Abandoning symmetrical wing extension while preserving symmetry for flapping angle to recover from roll-dominated perturbations indicates that bats can independently coordinate these degrees of freedom, which may be under distinct of neural control during unsteady locomotion.

P3-217 BOGAN, SN*; INGRAHAM, M; PLACE, SP; BOGAN, Samuel; Sonoma State University; *snbogan8@gmail.com*

Regulatory Origins of a Lost Inducible Heat Shock Response in Antarctic Fishes

The perciform suborder Notothenioidae is comprised of Antarctic and sub-Antarctic fishes, several of which have lost their ability to rapidly upregulate major heat shock proteins (HSPs) in response to stress. Rather, inducible HSPs such as the hsp70 and hsp90 families are constitutively expressed under normal environmental conditions and do not upregulate following oxidative damage to the cell. While it was initially suggested that the constitutive expression of HSPs resulted from constant cold-denaturation of the proteome, there is evidence to suggest that the trait is not environmentally controlled. Therefore, it is plausible that the trait is attributed to functional alterations to regulatory elements of the inducible heat shock response (HSR). In order to identify genomic divergence within Nothothenioidae that may confer the loss of an inducible HSR, we sequenced the complete coding region of the transcription factor HSF1 and cis-acting heat shock element (HSE) motifs across the genomes of two members of the notothenid family, the Antarctic notothen *Trematomus bernacchii*, which has lost induction of the HSR, and a temperate notothen exhibiting a classical HSR, *Notothenia angustata*. We have compared the degree of conservation between HSF1 orthologs in *T. bernacchii* and *N. angustata* to shed light on differences in the regulation of inducible HSPs among notothens. These results, in addition to preliminary data derived from HSE sequencing, provide mechanistic insight into how the regulation of inducible proteins is modified to confer constitutive expression or activation during adaptation.

107-2 BOGAN, SN*; MCMAHON, JB; PECHENIK, JA; PIRES, A; Sonoma State University, Tufts University, Dickinson College; *snbogan8@gmail.com*

Latent and Interactive Effects of Ocean Acidification and Nutrition Across the Larva to Juvenile Development of an Intertidal Gastropod

Ocean acidification (OA) poses a significant threat to calcifying invertebrates by negatively influencing shell deposition and growth in high pCO2 and low pH environments. Developmental responses to OA are often influenced by interactions between consecutive life history stages and between OA and additional environmental variables such as food availability. Effects of pH or pCO2 stress incurred during one life history stage can persist throughout proceeding stages. Abundant nutrition can buffer organismal responses of calcifying invertebrates to OA. Inversely, nutritional stress can function as a co-occurring stressor. It is plausible that the nature of such interactions between low pH and low nutrition changes as the life history of a calcifying invertebrate proceeds. We reared larvae and juveniles of the planktotrophic marine gastropod *Crepidula fornicata* through combined treatments of nutritional stress and low pH to monitor how multiple stressors endured during the larval stage affect juvenile performance. Shell growth responded non-linearly to decreasing seawater pH, significantly declining between pH 7.6 and pH 7.5. Deleterious effects from conditioning at pH 7.5 persisted across metamorphosis as a larval carry-over effect; juveniles that had been reared at pH 7.5 as larvae grew significantly slower than juveniles derived from pH 8.0 larval cultures. Larval conditioning at pH 7.6 reduced juvenile growth despite the absence of a negative impact on larval growth, demonstrating a latent effect. Optimal larval pH offset the impact of larval nutritional stress on competence for metamorphosis and offset carry-over effects of larval nutrition on juvenile growth, indicating the importance of interactions between OA and other stressors across life history transitions of marine invertebrates.

123-5 BOGANTES, V.E.*; HALANYCH, K.M; BOYLE, M.J.; Auburn University, Smithsonian Marine Station at Fort Pierce; *vikbogantes79@gmail.com*

Larval development of Pseudopolydora sp. (Spionidae, Annelida) from Florida

Spionid annelids are small (1 mm-5 cm) tubiculous (tube-dwelling) worms with a pair of long palps, that dominate shallow benthic sediments. Studies on annelid development are relatively extensive, although spionid developmental diversity has not been investigated with confocal laser scanning technology. Here, we describe development of musculature, ciliation patterns and serotonergic-positive elements of the nervous system during larval formation in *Pseudopolydora* sp. Adult worms were collected from the Indian River Lagoon in Florida during summer of 2017, and checked for egg capsules. Larval stages were isolated and prepared for compound and confocal laser scanning microscopy. Preliminary analyses show progressive anterior-posterior development of musculature associated with chaetal sacs, digestive system and larval body, as well as serotonergic nerves in the brain, circumesophageal connectives, and both cell bodies and axons along a pair of ventral nerve cords with posterior growth cones. Serotonergic elements also are associated with the chaetal sacs, and in planktotrophic larvae, left and right ventral cords connect in a looping pattern, anterior to the pygidium. Ciliation is extensive and includes multiple compound ciliary cells around the head, on and within the stomodeum and gut, and on the pygidium. Completely circularized trochal bands were not observed in these larval stages. Although developmental studies in annelids have increased over the last decade, the most detailed studies were performed with laboratory cultures of non-model species (e.g. *Platynereis dumerilii*, *Capitella teleta*). Comparative studies using confocal microscopy with understudied groups will broaden our understanding of evolutionary developmental patterns across Annelida.

P3-14 BOLDEN, IW; SEROY, SK*; ROBERTS, EA; SCHMEISSER, L; KOEHN, JZ; RILOMETO, C; ODANGO, E; BARROS, C; SACHS, JP; KLINGER, T; University of Washington, Pacific Resources for Education and Learning; *sseroy@uw.edu*

Climate-related community knowledge networks as a tool to increase learning in the context of environmental change

Pacific islands, countries, and territories (PICTs) are particularly vulnerable to sociocultural, economic and environmental impacts of climate change. Pohnpei, Federated States of Micronesia, experiences internal climate variability, severe droughts during El Niño, and externally forced variability due to climate change, both affecting water quality, public health, agriculture and resource management. Here, we present the outcomes of a collaboration between graduate students and a PICTs-focused non-profit organization to facilitate a climate-related knowledge network that addresses adaptation to climate-related vulnerabilities in Pohnpei. Through a series of workshop forums targeting elementary school science teachers, this network established lines of communication between educators, resource managers, stakeholders and environmental leaders, providing a forum for ongoing information exchange to encourage adaptation to climate change in island communities. Teacher participation in the workshop forums developed here further resulted in a marked increase in community engagement in other local and regional educational venues. The network serves as an interdisciplinary exportable model of a sustainable educational partnership and continues to work with local community members, recognizing the importance of relationships in maintaining a thriving knowledge network.

39-1 BOLINGER, S*; AVERHART, M; DUKE-SYLVESTER, S. M.; JOHNSON, E. I.; RAY, K; BOLINGER, Sarah; University of Louisiana - Lafayette, Audubon Louisiana, American Bird Conservancy; *sarah.bolinger@gmail.com*

EFFECTS OF DEPREDATION AND STORM SURGE ON HATCHING SUCCESS OF LEAST TERN NESTS ON A RENOURISHED SOUTHEAST LOUISIANA BEACH

To help forestall coastal erosion, Louisiana's Coastal Protection and Restoration Authority has instated beach renourishment programs, which help reduce the risk of storm surge for coastal marsh and human communities and provide ideal habitat for nesting Least Terns because they vastly increase the area of sparsely vegetated open beach. Previous data have suggested, however, that beach restoration has a mixed effect on nest success for these birds. Increased presence of mesopredators, which leads to lower hatching success, may in some circumstances create a population sink associated with restored beaches, but nests on restored beaches also appear less likely to be destroyed by floods and storm surge. We tested these predictions on Elmer's Island, in which the Caminada Headlands Phase II dune renourishment project was completed in late 2016. To quantify the effects of restoration on nesting success, we used program MARK to calculate daily nest survival (DNS) for 287 nests monitored in summer 2017, and modeled nest success with DNS evaluated at different intervals. Nest elevation, storm surge, predator density, and substrate/vegetation surrounding nests were used as covariates. Interactions between extreme high tide events and depredation risk may be complex, such that understanding these interactions and how restoration affects these risks is an important pursuit in researching the effects of coastal restoration on beach-nesting birds.

138-3 BOLLA, V; PAIG-TRAN, EWM*; California State University Fullerton; *empaig-tran@fullerton.edu*

New insights into manta ray feeding using a non-clogging, self-cleaning filter

Filtration is ubiquitous in nature and in engineered systems alike. Almost all filters suffer from varying degrees of particle clogging at the filter pore; however, mantas and devil rays appear to have solved this problem, allowing the animals to continuously filter particles from large volumes of water without clogging. Previously we showed that manta filters develop hydrocyclonic nets produced at the opening of the filter pore; presumably to separate particles smaller than the pore size of the filter through centrifugal forces. Our goal for this study was to document particle filtration at the hydrocyclonic nets and to estimate filtration efficiency over a wide range of plankton particle sizes (30-300micron) and two densities (1.05g cm^{-1} ; 2.0g cm^{-1}). We suspended biomimetic mobulid filters inside a flow tank and filmed particle filtration (particles were 5x smaller than the pore size) at the filter pores. We used dye streams to verify that the hydrocyclonic nets were acting as the primary mechanism of filtration. Dye streams also enabled us to visualize how changes to the filter (filter orientation, angle of filter, changes to the surface microstructure) and fluid velocity affect particle motion at the pore. Unexpectedly, the hydrocyclonic nets filtered particles using two distinct mechanisms. As expected, small particles became entrained within the cyclonic flow at the filter and were returned to the pharyngeal flow via centrifugal forces. However particles that interacted with the leading edge of the hydrocyclonic nets were accelerated toward the esophagus, never becoming entrained in the cyclonic flow. Filtering efficiencies for less dense particles ranged between 44-72% depending on the orientation and surface structure and particle size. Increased particle density resulted in decreased particle efficiency (36-57%).

43-6 BOMPHREY, RJ*; PHILLIPS, N; WALKER, SM; NAKATA, T; Royal Veterinary College, University of Leeds, Chiba University; *rbomphrey@rvc.ac.uk*

Aerodynamic imaging and aeroacoustic cues for surface detection in nocturnal mosquitoes

Flying animals must perceive and avoid obstacles, often in environments deprived of sensory cues. In particular, nocturnal mosquitoes must divert away from surfaces or land gently when visual cues are unavailable, indicating a short-range, non-visual collision avoidance mechanism. We hypothesised that this is mediated by mechanosensory feedback, with mosquitoes detecting and reacting to modulations of their own induced aerodynamic and acoustic fields as they enter ground- or wall-effect. We investigated the sensory information available for these two putative mechanisms for sensing obstacles through computational fluid dynamics and aeroacoustic simulations of low-altitude and near-wall mosquito flight. Our simulations are based on detailed wing kinematics extracted from high-speed recordings of free flying *Culex quinquefasciatus* mosquitoes. Results reveal areas of relative pressure changes that are associated with close proximity to the ground and wall planes and that could provide useful information to the flight controller: a mechanism we term ‘aerodynamic imaging'. Using a new computational aeroacoustic simulator, we also calculated the acoustic pressure distribution around the mosquito in the near and far fields. The simulations suggest a strong directionality in the magnitude and dominant frequencies of the acoustic signature that could be encoded to detect surface proximity and directional vectors, or for intraspecific communication. Using these insights we built and flew an aerial robotic prototype carrying the bioinspired sensor.

52-4 BOND, SR*; BAXEVANIS, AD; NHGRI, NIH, Bethesda, MD; *steve.bond@nih.gov*

Recursive Dynamic Markov clustering: A novel approach for classifying protein families

Inferred orthology (i.e., homology via speciation) among genes is commonly used to predict gene product function. Orthology is also a key consideration when classifying genes coherently and consistently across taxa, but the granularity of current prediction tools is too coarse to resolve clusters of orthologs (i.e., orthogroups) within specific gene families. As a result, classification is generally at the discretion of individual curators manually inspecting gene trees. Here, we present a method that improves granularity and greatly assists with classification.

This new method is called **Recursive Dynamic MCL** (**RD-MCL**), and it extends the popular Markov clustering algorithm used for identifying clusters in all-by-all similarity graphs. RD-MCL features four key innovations: a shift away from BLASTP-based similarity metrics in favor of more information-rich multiple sequence alignments, applying a scoring system to assess the quality of orthogroups, dynamic selection of optimized MCL parameters, and recursive decomposition of orthogroups to account for heterogeneous rates of evolution.

Simulation studies reveal improved precision when RD-MCL is compared to popular orthogroup prediction software such as OrthoMCL, OrthoFinder, and ProteinOrtho. These improvements are possible because RD-MCL has been developed specifically for analyzing individual protein families rather than the genomic-scale datasets these other methods excel at. Furthermore, applying RD-MCL to real protein families (including the innexin/pannexin superfamily and caspases) clearly delineates the internal evolutionary structure of these families and illustrates current weaknesses in the naming of genes in public databases, particularly in taxa outside the Chordata.

RD-MCL is open source and available for reuse without restriction.

P3-185 BOND, L*; STRICKLEN, B; GOULD, F; GERMAN, R; Northeast Ohio Medical University; *lbond1@neomed.edu*

Coordination of Swallowing and Respiration for Various Feeding Methods in Infant Pigs

All mammals make a transition from milk to solid food, or weaning. This critical change occurs due to the limited availability of mother's milk, and causes changes in the biomechanics of feeding, as well as the coordination of breathing and swallowing. Since the food and air pathways cross, we ask whether the timing of a swallow relative to respiration changes with the introduction of new food types. Four piglets, aged 26-31 days, were recorded using high speed videofluoroscopy while drinking milk or feed pellets mixed with barium. These images provided the exact swallow time, which we correlated with simultaneously recorded breathing data from a thoracic plethysmograph. Data included six feeding sequences per animal: 1 sequence drinking milk from a bowl until satiety; 4 sequences drinking 4oz from a bowl, immediately followed by no more than 8oz from a nipple; 1 sequence eating pellets. We measured the delay between time of the swallow and onset of thoracic inspiration. The timing of coordination between swallowing and respiration is similar in drinking from a bowl or a nipple. However, coordination is more variable in drinking from a bowl. When eating solid food, the time between swallowing and onset of inspiration is shorter, with low variability. These preliminary data suggest there is a difference in how the infants coordinate respiration cycles and swallowing among the different feeding methods used. The two adult feeding behaviors (bowl drinking, eating pellets) differ from the infant behavior (nipple drinking) in diverse ways. There is a complex pattern of change in neural coordination of swallowing and respiration at weaning in response to changes in feeding behavior, along with food type. Further experimentation is needed to draw more solid conclusions, such as working with older pigs to measure this coordination post weaning.

P2-16 BOND, EC*; FORSGREN, KL; California State University, Fullerton; *evelynbond@fullerton.edu*

Structural Complexity of Copulatory and Associated Reproductive Structures within the Family Embiotocidae (Teleostei)

The surfperches (Embiotocidae) are marine coastal fishes distributed along the eastern Pacific Ocean from Alaska to central Baja California. Surfperches are ecologically diverse and live in a variety of habitats including sandy bottoms, rocky reefs, kelp forests, and seagrass beds. Surfperches are among the approximately 500 fishes that exhibit internal fertilization and bear live young. During copulation, males utilize external copulatory structures (e.g., genital papilla, intromittent organs) to transfer spermatozeugmata, large bundles of sperm into the female reproductive tract. Surfperch copulatory structures have not been fully investigated and are not well understood. We hypothesized that surfperch male copulatory structure complexity would vary based on the primary habitat utilized by the species. We used paraffin histological techniques and scanning electron microscopy (SEM) to examine copulatory and associated reproductive structures in three surfperch species occupying different habitats. Walleye surfperch *(Hyperprosopon argenteum)* inhabit sandy bottoms and had a genital papilla anterior to the anal fin, which appears bulbous with posteriorly located paired fleshy plates. Shiner perch *(Cymatogaster aggregata)* are typically found in eelgrass beds and had a genital papilla and paired intromittent organs located on both sides of the anterior portion of the anal fin, whereas black perch *(Embiotoca jacksoni)* that live in rocky reefs only had paired intromittent organs located anteriorly on both sides of the anal fin. We have identified several differences in the complexity of surfperch external reproductive anatomy. Morphological structures have previously been directly linked with niche partitioning in surfperches, however our research is the first to investigate copulatory structures and diverse environments.

S10-2 BONIER, F*; MARTIN, PR; Queen's University; *bonierf@queensu.ca*

Environmental challenges, species interactions, and urban adaptation

Urbanization represents one of the most extreme transformations of the natural world. Most species cannot persist in urban environments, and yet some species thrive in cities. What determines which species merely persist and which species flourish in urban habitats? Direct, competitive interactions among closely-related species can impact how species respond to an array of environmental challenges, but their potential role in influencing species responses to urbanization is poorly understood. We used a citizen-science approach to compile a dataset spanning 260 of the world's largest cities and 296 species of bird, to test the role of direct competitive interactions and behavioral dominance in determining the occurrence of closely-related species in cities. We use these data to test predictions of 4 alternative hypotheses, and find convincing evidence to reject 3 of them and support only one. In exploring the breadth of these patterns, we find evidence for interesting variation in the role of competition.

105-2 BOOTH, AR*; ZOU, E; Nicholls State University; *abooth@g.clemson.edu*

Impact of Molt Disrupting BDE-28 on Epidermal Ecdysteroid Signalling in the Blue Crab, Callinectes sapidus

Polybrominated diphenyl ethers (PBDEs) are environmentally ubiquitous flame retardants that have been linked with altered endocrine function in a variety of organisms. A recent study identified BDE-28, one of the most prevalent PBDE congeners in aquatic environments, as a potent inhibitor of crustacean molting, but the mechanism of its action is still unclear. This study will examine the disruptive effects of BDE-28 on epidermal ecdysteroid signaling *in vitro* to illuminate a potential mechanism for molt disruption by this PBDE congener. Expression of the N-acetyl-β-glucosaminidase (NAG) gene in the epidermis will be used as the biomarker for ecdysteroid signaling. Using the recently developed epidermis-with-exoskeleton (EWE) tissue culture method, we will expose *Callinectes sapidus* epidermal tissues to varying levels of BDE-28 alone and in combination with the molting hormone 20-HE. The effects of BDE-28 and the inducibility of NAG will be measured by quantifying NAG gene expression in exposed tissues using RT-PCR. Initial results indicate possible suppression of epidermal ecdysteroid signaling due to a trend of decreasing NAG gene expression between exposures to 1 μM 20-HE alone and the binary treatment of 1 μM 20-HE and 1 μM BDE-28. Findings of this study will ultimately contribute to an improved understanding of the mechanisms of molt-disruption by this environmentally important PBDE congener.

16-2 BORGMANS, G*; VAN DAMME, R; University of Antwerp; *glenn.borgmans@uantwerpen.be*

The (dis)advantages of dominance in a multiple male group of A. carolinensis

The fact that establishing dominance relations in reptiles often involves aggressive behaviour and possible injuries makes it a concern for zoo management programs as well as private keepers and scientific research. While male dominance has mostly been investigated in dyadic encounters, our study looked at dominance in a multiple-male group. Ten groups of four *A. carolinensis* lizards were housed together to investigate the effects of dominance across multiple contexts such as access to food sources, reproduction and predation. Our results showed that dominant individuals had priority to food sources while also having a higher risk of predation. No differences were found between dominant and subordinate males in a context of reproduction. Dominant individuals did perform more social displays across different contexts. These behavioural results are linked to a number of physiological variables such as body weight, tail width and Heterophil to lymphocyte ratio to get a better view of the physiological effects of dominance in a multiple male group.

P1-145 BORRELLI, S.T.*; CHANDLER, C.H.; State University of New York at Oswego; *sborrell@oswego.edu*

Assessment of sexual dimorphism of the terrestrial isopod Trachelipus rathkei

In many species, males and females show important phenotypic differences. Nevertheless, the evolution of sex-specific traits is not fully understood, so investigating the evolutionary pathway of sexually dimorphic traits could provide insight as to how new genetic information along with novel traits originate. In many terrestrial isopod species, males have more and larger bristles on their first and second pairs of legs than females, similar in some ways to the well studied sex combs of Drosophila species. The goals of this experiment are: first, to characterize variation in leg bristle sexual dimorphism across terrestrial isopod species; and second, to look for evidence of convergent evolution at the molecular level by looking at the expression patterns of genes homologous to those involved in the development of sex combs in Drosophila. I expect my results to show Scr and dsx homologs to be expressed at higher levels in the first two male legs in comparison to other male legs and in any legs of females.

P3-104 BOSTWICK, CJ*; MOROZ, TP; MOROZ, LL; Univ. of Florida, Whitney Lab; *cbostwick87@gmail.com*

Identifying cAMP-dependent genes and how plasticity induces alterations in the nervous system of the sea hare Aplysia californica

The molecule cyclic adenosine monophosphate (cAMP) regulates a variety of cellular processes, including neuronal plasticity. Molecules involved in the initial cAMP-dependent signaling cascade have been studied, but the molecules "downstream" in the signaling cascade are relatively unknown. To thoroughly characterize the cAMP pathway, we utilized high-throughput-sequencing to query the nervous cells of a classic neuroscience model, the sea hare *Aplysia californica*. We treated the *Aplysia* central nervous system (CNS) with a cAMP analog (8-Br-cAMP) for various periods of time to activate the cellular cAMP signaling pathway. We were able to identify cAMP-dependent genes that are differentially expressed between the various ganglia subtypes of the *Aplysia* CNS as well the abundance of genes within ganglia over the time-course of treatment. We discovered hundreds of differentially expressed transcripts by time and tissue. These transcripts encode chromatin-remodeling genes, transcription factors, ion channels and receptors, amongst others. A portion of the transcripts are uncharacterized and potentially unique to *Aplysia*. These uncharacterized transcripts may influence gene expression by posttranscriptionally modifying RNAs, facilitating protein-protein interactions, or be involved in novel cell signaling. We also found long noncoding RNAs (lncRNA) that may be involved in unidentified regulatory roles within the CNS. Our transcriptional study of the cAMP-dependent signaling cascade within the *Aplysia* CNS can potentially provide a foundation to understanding the dynamics of this crucial signaling pathway and specifically its effects on long-term memory and synaptic plasticity.

P1-231 BRADY, KN*; VOISIN, D; WELCH, J; KOVACS, JL; Spelman College, Georgia State University; *kbrady@scmail.spelman.edu*

Characterizing the microbiome of honey

On nearly every surface and inside nearly every organism there are millions of tiny microbes that are invisible to the naked eye. These tiny microbes include bacteria, fungi, viruses, and millions of yet uncharacterized species. Some of these microbes, known as symbionts, live in symbiosis on or within other organisms. Honeybees (Apis mellifera), like most insects, host symbionts in their guts. Previous research has identified and characterized nine bacterial species clusters that dominate the gut microbiome of honeybees. While the microbes in their hives and honey have not been as well characterized, we know that honeybees come into contact with a variety of microbes while collecting nectar in order to produce honey. The different species of these microbes that are present may depend on the season and region the hives that the honeybees are located in, as well as the gut microbial composition of worker bees in the hive. What microbial symbionts are present in honey? Are these symbionts different as the seasons change? Are there differences among hives in different regions? How are these microbes related to the ones present in the guts of honeybees? In this study, DNA meta-barcoding will be used to assess whether there are regional and temporal differences in the symbiotic environment of the guts of worker bees and the symbionts in stored honey.

9-5 BRANDT, EE*; ROBERTS, KT; ELIAS, DO; Univ. of California, Berkeley; *eebrandt@berkeley.edu*

Metabolic Rate and Critical Thermal Limits across Male and Female Habronattus Jumping Spider Species

Temperature can have wide-ranging and dramatic effects on poikilothermic animals across all levels of biological organization, from metabolism to interspecific interactions. Elevational gradients are a particularly interesting system in which to examine this, as temperatures can vary widely across different temporal and spatial scales. This study investigates how, across an elevational gradient, metabolic rates and critical thermal limits vary within and between sexes and species of jumping spiders in the genus *Habronattus*. Using a repeated measures design, we measured metabolic rate in males and females of six different species in the Santa Rita Mountains in Arizona: *H. clypeatus*, *H. geronimoi*, *H. pugillis*, *H. conjunctus*, *H. hallani*, and *H. virgulatus*. After collecting all animals and holding them at lab temperature (~22 °C) for at least 2 weeks we measured VCO2 produced using stop-flow respirometry techniques. Each individual was incubated at 7 different temperature treatments (from 10°-40°C, at 5 degree intervals). We also assessed CTmin and CTmax for each sex and species. We found several differences between sexes and species in their thermal physiology. We suggest that variation in thermally related physiology corresponds to their elevational range and is likely important in driving species distributions across the elevational gradient.

35-4 BRASMER, RH*; RAMIREZ, RW; WOLF, BO; University of New Mexico; *wolf@unm.edu*

Comparative Thermoregulation of White-tailed Antelope Ground Squirrels (Ammospermophilus leucurus) in the Mojave

The White-tailed Antelope Squirrel (*Ammospermophilus leucurus*) is a diurnal rodent whose range extends from deserts of the Great Basin to Baja California, and thus must cope with high environmental temperatures during its day-to-day life. Increased temperatures and increases in extreme heat events from rapid climate change may importantly affect the behavior and physiology of these animals in the future. In order to understand the current performance of antelope ground squirrels and their overall flexibility we investigated the thermoregulatory capabilities of *A. leucurus* during summer and winter at multiple sites with differing elevations. We used flow-through respirometry to measure resting metabolic rate (RMR), evaporative water loss (EWL), and body temperature (T_b) in squirrels that were exposed to air temperatures (T_a) ranging from 15 - 52 °C. Measurements were taken at multiple sites at different elevations: Zzyzx (900ft asl), Joshua Tree (2500ft asl), Mid-hills (3000ft asl) and Mid-hills High (5000ft asl). Squirrels were very heat tolerant and able to evaporate large quantities of water when T_a exceeded T_b. While the breadth of the thermoneutral zone (TNZ) at Joshua Tree appears to have decreased from the Winter to the Summer, the breadth of the TNZ at Zzyzx appears to have broadened. During summer the mean RMR decreased with increasing altitude and was 5.9, 4.5, and 4.1 mW/g at Joshua Tree, Mid-hills, and Mid-hills High, respectively.

P1-298 BRASSEY, CA*; KITCHENER, AC; BEHNSEN, J; GARDINER, JD; Manchester Metropolitan University; *c.brassey@mmu.ac.uk*

The Role of Sexual Selection in Shaping the Carnivoran Baculum

Genitals often comprise the most morphologically diverse and fastest evolving structures within a group. New studies have provided compelling evidence that sexual selection is driving this divergence in genital morphology, and directly link genital shape to reproductive success. Within mammals, the Carnivora are renowned for males possessing a mineralized element (the baculum) within the glans of the penis, which is extremely diverse in shape. Baculum *size* has previously been found to be under direct sexual selection. However, the extent to which baculum *shape* is driven by sexual selection in Carnivora is unknown, in part due to methodological difficulties associated with quantifying shape change in such diverse structures. We use a new method (α-shapes) for quantifying shape complexity in the carnivoran baculum, outside the traditional paradigm of geometric morphometrics. We hypothesise that baculum α-shape complexity will correlate positively with relative testes mass, a proxy for post-copulatory sexual selection. Using microCT data of 77 species, spanning 11 Carnivoran families, we calculate whole-baculum α-shape complexity, in addition to α-shape complexity at the tip, midshaft and base. Across Carnivora, α-shape complexity of the baculum was positively correlated with relative testes mass, suggesting a role for post-copulatory sexual selection in driving baculum shape. Furthermore, whilst absolute α-shape complexity was greatest in the tip, the rate of evolution in α was fastest at midshaft. This surprising results suggests more attention should be paid to the baculum midshaft, particularly the urethral groove and its potential role in protecting the urethra and ensuring sperm delivery during copula.

P1-80 BRAUN, L/J*; DILLMAN, A; Univ. of California, Riverside; *lbrau002@ucr.edu*

Entomopathogenic Nematode Infective Juveniles Stimulated by Physical Contact with Host Cuticles Have Enhanced Their Behavioral Response to Host-Specific Odors

Previous research demonstrated that *Steinernema carpocapsae* infective juveniles (IJs) exposed to a host cuticle were more attracted towards certain host volatile odors. We wanted to test the specificity of attraction that results from exposure to host cuticle. To do so, S. carpocapsae host recognition behavior was analyzed after stimulating IJs by allowing them to physically interact with *Galleria mellonella* cuticles. We measured the behavioral response and the percentage of the population participating in chemotaxis behavior to multiple host odors in volatile chemotaxis assays after the IJs were exposed to the host cuticle of *G. mellonella* or a sham control. We found that exposure to host cuticles resulted in a higher percentage of the population participating in chemotactic behavior. We tested whether exposure to live host cuticle or dead host cuticle resulted in a different response and found that a higher percentage of IJs exposed to a live host cuticle participated in chemotactic behavior than IJs exposed to a dead host cuticle, but that IJs exposed to a dead host demonstrated significantly higher participation than was observed for non-stimulated IJs. To test whether the increase in IJ participation in host-seeking behaviors after exposure to a live host cuticle was specific, we exposed stimulated IJs to a known repulsive odor, a neutral odor, and a known attractant. We found that stimulation of IJs through physical contact with a host cuticle induces a specific enhancement of host-seeking behavior to host-specific odors rather than a general increased chemotactic response to all volatile stimuli. Future work will be aimed at elucidating the mechanism through which contact with live host cuticle stimulates increased behavioral response.

P3-106 BREDA, JB*; FRENCH, KA; KRISTAN, WB; TODD, KL; Westminster College, Univ. of California, San Diego; *jbreda19@gmail.com*

Homologous neurons play similar roles in reproductive-behavior circuits

A long-standing hypothesis in the field of neuroethology has been that organisms performing similar behaviors have similar underlying neuronal circuitry. Recently, though, studies focused on locomotion have shown that this many not necessarily be true. Work in sea slugs has demonstrated that homologous behaviors can be generated by a variety of neuronal connections. Our work looks at reproductive behaviors and asks whether those behaviors are mediated by the same neuronal connections in two species of leech. Research in *Hirudo verbana* has shown that copulatory reproduction is mediated by a neurohormone, hirudotocin, which is stored in and is released from a circuit of characterized neurons called Leydig Cells. When this circuit is stimulated, a progression of fictive behaviors consistent with reproduction is induced. A second leech, *Macrobdella decora*, has the same reproductive strategy as *H. verbana*, including a similar progression of behaviors. Using immunohistochemistry and electrophysiology, we have identified Leydig Cell homologs in *M. decora*. Additionally, when we inject either *M. decora* or *H. verbana* with a hormone similar to hirudotocin, we observe reproductive-behavior output that is nearly identical. This may indicate that the underlying circuitry is similar. We intend to compare these species further through electrophysiological characterization of the Leydig cell network in *M. decora*. By fulling characterizing the Leydig Cell network in both species we will be able to clarify the relationship between reproductive behavior and neuronal circuitry in leeches and give insight as to how neural circuits evolve across species.

114-2 BRESSMAN , NB*; SIMMS, M; ASHLEY-ROSS, MA; Wake Forest University; *bresnr16@wfu.edu*

Where do fish go when stranded on land? Terrestrial orientation and navigation of the mangrove rivulus, Kryptolebias marmoratus

It is well-established that many fishes will go onto land for a variety of reasons, from searching for better resources to avoiding predation. However, little is known about how fish determine where to go when on land, and which senses they use for terrestrial navigation. The goals of the present study were to determine which sensory cues the mangrove rivulus (*Kryptolebias marmoratus*), a quasi-amphibious, hermaphroditic fish, use to orient and navigate in an unfamiliar terrestrial environment. In a laboratory setting, *K. marmoratus* were placed on a terrestrial test arena and exposed to a variety of visual stimuli, as well as a slope, to determine the role of visual cues and the vestibular-otolith system in their terrestrial navigation. Circular statistics were used to determine the mean direction of travel in each treatment. Overall, *K. marmoratus* moved (1) toward reflective surfaces, supporting the findings of previous studies that found fish to use vision - and specifically the reflection of light as a cue - to navigate while on land; (2) toward water; (3) toward dark coloration, which may be associated with shade; and (4) toward orange coloration. Males showed a stronger preference for moving toward orange coloration than hermaphrodites, suggesting that the response may be associated with male-male competition, since only males display orange coloration. A slope also had a significant effect on orientation, with more movement downhill, suggesting the otolith-vestibular system is important for the terrestrial orientation of *K. marmoratus*. By understanding the orientation and navigation of extant amphibious fishes, we may be able to infer how sensory biology and behavior evolved in relation to the invasion of land by amphibious vertebrates millions of years ago.

P2-127 BREWER, VB*; MABRY, KE; SEWALL, KB; New Mexico State University, Virginia Polytechnic Institute and State University; *vbrewer@nmsu.edu*

Effects of Urbanization on Song Sparrow Genetic Structure

Urbanization fragments landscapes and can impede the movement of organisms through their environment, which can decrease population connectivity. We investigated the effects of urbanization on genetic diversity and genetic structure in rural and urban populations of song sparrows (*Melospiza melodia*). We genotyped 211 song sparrows captured at 7 sites along a gradient of urbanization in and around Blacksburg, VA, using 7 polymorphic microsatellite loci. We used GENEALEX and STRUCTURE to assess genetic diversity and genetic structure among capture sites. We found that genetic diversity was comparable between urban and rural song sparrow populations, and found no significant genetic structure. Other studies have found that urbanization is associated with increased genetic differentiation among populations of song sparrows. However, most previous studies have been conducted in more highly urbanized environments than this study, and have genotyped birds at more microsatellite loci. We are currently adding additional loci to our dataset, but results to date are consistent with genetic panmixia in a less urbanized environment.

26-3 BRINK, KS*; CHIBA, K; RICHMAN, JM; University of British Columbia, University of Toronto; *brinkkir@dentistry.ubc.ca*

Timing of Tooth Development and Tooth Replacement in Homodont and Heterodont Dentitions

Patterning of the vertebrate dentition is an extensively studied topic in the fields of palaeontology and developmental biology. It is well known that animals with continuous tooth replacement (polyphyodonty) replace their teeth in distinct waves around the mouth, the timing of which is predictable over long time periods. The slowing of tooth replacement in the synapsid lineage has been posited as one of the key mechanisms in the evolution of diphyodont (one replacement) heterodont dentitions from polyphyodont, homodont ancestors. As most studies on the patterning and timing of polyphyodonty have focused on homodont animals, the relationship between tooth size and shape and wave replacement patterns is unknown. Using historical x-ray data of polyphyodont homodont (*Iguana*, n=12) and heterodont reptiles [*Dracaena* (n=2), *Varanus* (n=3), *Teius* (n=2), and *Alligator* (n=2)] collected monthly for up to two years, the timing of tooth development versus tooth replacement can be determined. Results in all animals show normal, predictable wave replacement patterns in the dentition. In the homodont *Iguana*, the timing of tooth development and tooth replacement is tightly correlated. However, in the heterodont reptiles, the developmental time is different between teeth: smaller teeth take one or two months to develop before eruption, while larger teeth take up to five months. Additionally, replacement waves slow throughout the life of the animal as teeth get larger with subsequent replacements. The results of this study in reptilian model organisms suggest that larger, more complex teeth take more time to develop than smaller, simple teeth in the same jaw. Therefore, the slowing of tooth replacement over evolutionary time is likely a key mechanism in the development of heterodont dentitions.

2-1 BROCKLEHURST, RJ*; MORITZ, S; CODD, J; MANNING, PL; BRAINERD, EL; SELLERS, WI; University of Manchester, Brown University, College of Charleston; *robert.brocklehurst-2@postgrad.manchester.ac.uk*

Making Morphology Move: XROMM Ventilation Kinematics of Extant Archosaurs and Reconstructing Rib Motion in Fossils

Both modern birds and crocodilians have derived respiratory systems with divergent morphologies. This is coupled with divergent modifications to the ribcage, and differences in the mechanics of ventilation between these two groups. However, understanding the co-evolution of ribcage morphology and ventilation mechanics in living archosaurs has been hindered by a lack of integration between kinematic and anatomical data, which in turn creates difficulties in reconstructing motion in fossils. Here, we employ a joint-based approach to represent both bone morphology and motion. *In vivo* rib kinematics were recorded during ventilation in living crocodilians and birds using XROMM (X-ray reconstruction of moving morphology), with motion measured relative to the articular surfaces of the costovertebral joint; axes of rib translation and rotation were defined with respect to specific homologous landmarks on the ribs and vertebrae. This approach then served as the basis for "scientific motion transfer", applying motion patterns observed in modern archosaurs to their fossil relatives- specifically, non-avian dinosaurs- in a framework grounded in the anatomy of the costovertebral joint. This new approach provides a testable and repeatable way of predicting ventilation kinematics in extinct taxa. Morphometric analysis of archosaur vertebral morphology suggest that dinosaurs had costovertebral joints most similar to modern birds, and may have employed bird-like rib kinematics. However, the initial XROMM results also show that bony morphology alone is not a good predictor of rib motion, and greater consideration should be given to the soft-tissue anatomy of the costovertebral joint.

27-1 BROTHERS, JR*; LOHMANN, KJ; University of North Carolina; *brotherj@live.unc.edu*

Magnetic Navigation and Natal Homing in Mass Nesting Sea Turtles

Diverse animals migrate tremendous distances before returning to reproduce in the same location where they began life. An extreme example of this behavior called natal homing culminates in Ostional, Costa Rica, where hundreds of thousands of sea turtles return to nest in synchrony on a 4km stretch of beach. Despite strong evidence that all sea turtle species display natal homing, little is known about how it is accomplished. One recent idea, known as the geomagnetic imprinting hypothesis, notes that sea turtles detect Earth's magnetic field and use it to navigate. Moreover, Earth's field varies across the globe and different geographic areas are characterized by unique magnetic signatures. Thus, hatchling turtles might learn the magnetic coordinates of their natal beach and use this information to return as adults. To investigate a central tenet of this hypothesis, that adult turtles use magnetic navigation to locate the nesting beach, we traveled to Ostional and captured female turtles as they crawled onto the beach. We tethered each turtle in a water-filled arena inside a magnetic coil system designed to precisely control the magnetic field within the arena. We then exposed the turtles to the magnetic signature that exists 500km northwest of the nesting beach, a location within the turtles' migratory range, and monitored their swimming direction in response. If turtles use Earth's field to identify their natal beach we expect them to swim southeast in response to this magnetic displacement. Initial analyses confirmed this prediction: in response to the magnetic field that exists 500km northwest of the nesting beach turtles were, as a group, significantly oriented southeast. These preliminary findings are consistent with the geomagnetic imprinting hypothesis and suggest turtles use magnetic navigation to locate their nesting beach.

P2-180 BROWN, CE*; DEBAN, SM; University of South Florida; *cbrown43@mail.usf.edu*

Jumping in Arboreal Salamanders: The Role of the Hind Limbs

Jumping performance can have important implications for an animal's fitness by expanding its ability to evade predators and alter its microhabitat. Jumping in terrestrial plethodontid salamanders is achieved through lateral bending and rapid unbending of the trunk, an action powered by axial musculature. Scansorial plethodontids, some of which are known to utilize arboreal habitats, tend to have more robust limbs and digits, but their jumping has yet to be described. For salamanders occupying canopy niches, jumping could be an efficient approach to descent in response to environmental or predatory cues. Given differences in morphology and habitat use it stands to reason that scansorial plethodontids differ in both jumping biomechanics and performance when compared with terrestrial plethodontids. We compared jumping kinematics in several species of plethodontid salamanders, including arboreal species of the genus *Aneides*, using high speed imaging and kinematic analysis. Salamanders of the genus *Aneides* exhibited lower average total and relative jumping distances when compared with the terrestrial plethodontids *Eurycea*, *Desmognathus*, and *Plethodon*, possibly due to more subtle trunk bending. The kinematic analyses suggest that the hind limbs contribute significantly more energy to jumping in arboreal salamanders when compared with closely related terrestrial species that rely primarily on trunk bending and unbending. This suggests an alternative, previously undescribed jumping mechanism in salamanders that may reflect an arboreous lifestyle. Future research will focus on the aerial descent of climbing salamanders after a fall or jump.

P2-150 BROWN, ER*; PAVLICK, CR; PETANIDOU, T; TSCHEULIN, T; GONZALEZ, VH; AGOSTO-RIVERA, JL; HRANITZ, JM; BARTHELL, JF; University of Massachusetts Amherst, Bloomsburg University of Pennsylvania, University of the Aegean, Mytilene, GREECE, University of the Aegean, Mytilene, GREECE, University of Kansas, Lawrence, University of Puerto Rico, Rio Piedras, University of Central Oklahoma, Edmond; *emirbrown@umass.edu*

Temporal Niches of Two Pollinating Bees of Field Bindweed (Convolvulus arvensis, Convolvulaceae)

On Lesvos (GREECE), we studied the temporal foraging behavior of two primary bee pollinators of field bindweed (*Convolvulus arvensis*), a native weed of the Mediterranean region. We observed *Lasioglossum malachurum*, a eusocial generalist, and *Systropha curvicornis*, a solitary specialist, to be abundant pollinators of *C. arvensis* on the island. Knowing both species compete for *C. arvensis*, we hypothesized the bees have different temporal foraging niches. Visitation in quadrats at two field sites revealed temporal niche separation, wherein *L. malachurum* visited *C. arvensis* early while *S. curvicornis* visitation peaked later in the morning. To further understand the niches of these two species, we used multiple linear regression to test for relationships between visitation and five environmental variables: the number of partially open *C. arvensis* flowers, the number of fully open *C. arvensis* flowers, relative humidity, temperature, and light intensity. *S. curvicornis* visitation was positively related with the number of fully open *C. arvensis* flowers. *L. malachurum* was positively related with the number of partially open *C. arvensis* flowers and the number of fully open *C. arvensis* flowers. Visitation by *L. malachurum* was negatively associated with light intensity. These results confirm our observations that *L. malachurum* visited *C. arvensis* early in the morning when the flowers were only beginning to open while *S. curvicornis* visited the flowers only when they were fully open.

P3-122 BROWN, K*; MCCANN, M.K; BIGGAR, E; ZIATEK, S; PUMILIO, J; JIMENEZ, A.G.; Colgate University; *kbrown@colgate.edu*

The utilization of soundscape ecology to measure and track changes to biodiversity in the forests surrounding Colgate University

An ecosystem is characterized by a number of geographic and biological factors, but often overlooked is the role of sound in an ecosystem. Soundscape ecology is the study of the acoustic component of an ecosystem, which is made up of three types of sound: natural sound from living organisms (biophony), natural sound not from living organisms (geophony), and sound generated by humans (anthrophony). These sounds, their sources, and their interactions can often reveal important information about the environment. As Colgate University continues to make decisions about how to manage its landscape and forested areas and temperatures continue to rise due to climate change, soundscapes can reveal how these changes impact biodiversity and abundance in the forested land around campus. Thus, by recording and analyzing the soundscapes of Colgate University's forests, we can measure the health of this land and track changes that occur over time. While many organisms can be heard in these soundscape recordings, the most acoustically prominent are migratory songbirds that reside in the forests during the summer. As a result, we collected recordings with the intention of focusing on the vocalizations of birds. We used microphones to gather soundscape recordings from specific locations in the forests around Colgate University at dawn and dusk, the times of the day when birds are most vocal. Using R software, we computed indices for measuring biodiversity and the levels of anthropogenic disturbance within the forest. We found that as temperatures rose across the summer season, the levels of bioacoustic activity decreased within each recording, implying that of rising temperatures may increase biological silence in these ecosystems.

P3-133 BROWN, KN*; JACOBS, MW; McDaniel College ; *knb004@mcdaniel.edu*

How do Large Conspecific Predators Affect the Behavior of Juvenile Carcinus maenas?

Within intertidal ecosystems smaller organisms in high density populations face predation from larger organisms and competition from similarly sized organisms. As a result, they may experience a trade-off between foraging and sheltering. Across North America *Carcinus maenas*, or the European green crab, is an invasive species. The behavior of juvenile green crabs is understudied. We previously found that smaller juvenile crabs (5-10 mm carapace width, CW) spent a larger proportion of their time sheltering than larger juveniles (20-25 mm CW). Since green crabs are known to be cannibalistic at high densities, we hypothesized that the difference in sheltering behavior between small and large juveniles might change with the presence of a conspecific predator (30-40 mm CW). In an artificial setting, crab behavior was studied through video analysis. Preliminary data suggest that small crabs in the presence of conspecific predators allocate more time to sheltering. Large crabs in the presence of conspecific predators spent more time foraging. A shift in behavior of smaller individuals in the presence of predator may provide information on tradeoffs and conflicts individuals experience within a population. Understanding conspecific prey behavior in the presence of a predator may lead to a better understanding of demographical conflicts within *C. maenas* and potentially other decapods.

P3-127 BROWN , E*; FERNANDEZ , A; METZLER, E; PAVLICK, C; RIVERA-FIGUEROA, V; SALAGUINTO, T; GONZALEZ, V; AGOSTO-RIVERA, J; HRANITZ, JM; PETANIDOU, T; BARTHELL, JF; Univ. Massachusetts, Univ. Maryland Baltimore County, Salem College, Bloomsburg Univ., Univ. Puerto Rico, Río Píedras, Whitman College, Univ. Kansas, Univ.Aegean, Univ. Central Oklahoma; *jbarthell@uco.edu*

Carpenter Bee Foraging Patterns at Chasteberry Bushes (Vitex agnus-castus L.) on the Greek Island of Lesvos

A mark-recapture study of carpenter bee (*Xylocopa*) species at chasteberry bushes (*Vitex agnus-castus*) was conducted on the island of Lesvos (Greece). Bees were color-coded with paint marks so as to identify their capture sites; collections were repeated during a comparable period of time on subsequent days. White and blue morphs of the bushes of this plant species were specifically compared with one another to detect a preference by carpenter bees for either color. Although return rates were too low to detect significant differences in foraging fidelity by any carpenter bee species, we did note that, during our collection efforts, three species of carpenter bees foraged in a manner that suggests they have differing circadian rhythms: matinal, diurnal and/or crepuscular. Our results most likely reflect differences in spatial and temporal foraging scales wherein the relatively large-bodied and strong-flying carpenter bees traverse greater distances during the earlier and later periods of the day in order to avoid intense heat. The smallest species, *Xylocopa violacea*, was collected more often during the heat of the day while the remaining species, *Xylocopa oliveri*, visits only very early or very late in the day. These findings may have implications for understanding how body size relates to foraging times and as a thermoregulatory response to daily temperature cycles. Indeed, we predict that the circadian rhythm cycles endogenous to the bees will reflect their foraging habits.

P1-208 BROWN, , S*; NAGLE, L; AHEARN, GA; Univ. of North Florida, Jacksonville; *gahearn@unf.edu*

Ocean acidification: Effect of pH on calcium uptake by gill branchiostegites of American lobster, Homarus americanus

Atmospheric CO_2 interacts with seawater to cause a decrease in oceanic pH. Lowering the pH of oceanic waters results in dissolution of the calcium carbonate exoskeletons and shells of many marine invertebrates. This study aimed at determining whether increased proton concentrations at lower pH levels lead to a decrease in calcium uptake by animal gills. Transport competition between the two cations may lead to reduced calcium availability at sites of calcification. Lobster branchiostegite epithelia were removed from both gill chambers, homogenized in hypotonic buffers, and differentially centrifuged resulting in a semi-purified pellet of plasma membrane vesicles. Vesicles were loaded with a mannitol medium at pH 7.0 and incubated for 10 min in a similar medium containing 1 mM 45CaCl2 at pH 6.0, 6.5, 7.0, 7.5, 8.0 and 8.5. 45Ca uptakes at pH 6.0, 6.5 and 7.0 were low and not significantly different from one another ($p > 0.05$), likely representing non-specific binding. 45Ca uptake increased significantly ($p < 0.02$) from pH 7.0 to 8.5 with maximal uptake at the highest pH. 45Ca uptake at pH 6.0 was a linear function of calcium concentration, suggesting increased non-specific binding with elevated 45Ca concentration. In contrast, 45Ca uptake at pH 8.0 was a biphasic function of calcium concentrations, suggesting the presence of a putative calcium transporter plus non-specific binding. Results support the presence of at least one gill branchiostegite calcium transport protein that was inhibited by increasing seawater proton concentrations.

P2-15 BRUSCH IV, GA*; KAMINSKY, B; LOURDAIS, O; DENARDO, DF; Arizona State University, Centre d'Etudes Biologiques de Chizé, France; *bruschg@gmail.com*

The Relationship Between Maternal Hydration and Immune Function: Impacts on Egg and Offspring Quality

The immune system is essential for survival and its performance can vary depending on the physiological state of the organism (i.e., energetic state, life-stage, etc.). Much of the current research into immune function dynamics has focused on energy balance as the driver of changes in immune function; conversely, the role of water has received little attention. Water is a fundamental resource and essential to life; dehydration typically has negative impacts on most major physiological functions although recent research has found a positive relationship between dehydration and innate immune performance. However, these studies examined the effects of dehydration on immunity in adults and did not explore how maternal dehydration might affect her reproductive output. Thus, we examined the trans-generational effects of hydration state during gravidity in adult female Children's pythons (*Antaresia childreni*) and how hydric imbalances impact egg and offspring quality. Females were either given access to water or water restricted while gravid, and we evaluated osmolality and innate immune function of freshly oviposited eggs. We also dehydrated late-stage eggs, and then collected body fluid samples from control and dehydrated embryos 3 days prior to hatching. We detected no negative effects of maternal dehydration on the oviposited eggs, suggesting the eggs are buffered from maternal hydric state. Additionally, we found that neonates just prior to hatching are prone to dehydration and that it is positively correlated with increased innate immune performance, similar to adults.

141-3 BRUSCH IV, GA*; KAMINSKY, B; LOURDAIS, O; DENARDO, DF; Arizona State University, Centre d'Etudes Biologiques de Chizé, France; *bruschg@gmail.com*

Internal Source of Metabolic Substrates Used for Reproduction Varies Based on Female Hydration State: Muscle as an Internal Water Depot.

Water is an essential resource, and animals obtain water as free water, dietary water, and metabolic water. However, when sources of new water are limited, animals can reallocate water within their body. Recent research suggests that organisms under dehydrating conditions may increase the catabolism of muscle as a means of maintaining water balance, since muscle contains a greater proportion of water than does fat, yielding more water for reallocation. We investigated the interactive effects of reproductive investment and water deprivation on fat and muscle catabolism in female Children's pythons (*Antaresia childreni*), a species that reproduces during a highly food- and water-limited dry season. Both reproductive and non-reproductive snake were maintained at a constant temperature and without food. Half the females of each group were deprived of water for three weeks at the time when reproductive females were gravid. We used several morphometric and biochemical assessments to measure changes in lipid and protein catabolism when reproductive females were in late vitellogenesis and late gravidity. Not surprisingly, we found that both protein and fat catabolism was significantly greater during vitellogenesis compared to the gravid and non-reproductive states. Of greater interest, reproductive females that were water-restricted during gravidity catabolized significantly higher amounts of muscle than did non-reproductive females or gravid females with access to water. Our results provide evidence that, when water availability is limited, muscle can serve as a depot for reallocation to other water-demanding processes.

141-4 BRYLA, A*; DZIALO, M; DEMORANVILE, K; SADOWSKA, ET; TROST, L; PIERCE, BJ; MCWILLIAMS, SR; BAUCHINGER, U; Jagiellonian University, University of Rhode Island, Max Planck Institute for Ornithology, Sacred Heart University, University of Rhode Island; *amadeusz.bryla@doctoral.uj.edu.pl*

Dietary Unsaturated Fatty Acids Affect Oxygen Delivery System In Migratory Birds

Saturation level of fatty acids (FA) in birds' tissues is known to affect the energetic costs of short and long-term flights: polyunsaturated fatty acid (PUFA) fed birds fly about 10% cheaper compared to monounsaturated fatty acid (MUFA) fed birds, but the underlying mechanism remains unknown. Membrane hypothesis, proposes that the saturation level of FA affects the fluidity of cell membranes and thus their functions across membrane processes. Specifically, FA composition of red blood cells (RBC) membranes can affect their deformability and thus cost of transport of blood. We fed 37 European Starlings with either a diet rich in PUFA or MUFA and split each diet group into flying birds (about 900 km in a wind-tunnel) and non-flying birds. For all birds, we measured basal metabolic rate (BMR) and haematological variables (HVs) (haematocrit, haemoglobin content, number and size of RBC). Neither BMR, nor any HVs were different between diet and training groups. The relationships between BMR and both, haemoglobin and haematocrit were significantly affected by diet, not training (individual correlations BMR-haemoglobin and BMR-haematocrit for each diet did not differ from 0). Significant interactions suggest different diet effect on HVs. Significant contribution of HVs, here haemoglobin content and haematocrit, to whole animal energy expenditure might be even more pronounced when considering flight costs instead of BMR. Lower heart-specific energy use for circulation of blood caused by lower blood viscosity due to more deformable cells for PUFA-fed birds may contribute to differences in flight costs.

125-7 BRZEK, P*; SELEWESTRUK, P; GEBCZYNSKI, A; KSIAZEK, A; SADOWSKA, J; NEDERGAARD, J; KONARZEWSKI, M; Univ. of Bialystok, Poland, Stockholm Univ., Sweden; *brzek@uwb.edu.pl*

Physiological and Behavioral Correlates of Selection for High Swim-Induced Peak Metabolic Rate in Laboratory Mice: Implications for the Aerobic Capacity Model of the Evolution of Endothermy

The aerobic capacity model of the evolution of endothermy posits that high basal metabolic rate (BMR), typical of endotherms, evolved as a correlated response to selection for high peak metabolic rate (PMR) elicited by e.g. locomotor activity bursts or thermogenesis. To test the model we studied 4 lines of laboratory mice artificially selected for high PMR elicited by swimming in water at 25 °C along with 4 control (randomly selected) lines. Our selection therefore affected both locomotor activity and metabolic response to sudden cold stress. Here, we compared thermogenic capacity and responses to short- and long-term exposure to low ambient temperature (4 °C) in selected mice and randomly bred controls. Selection significantly increased non-shivering thermogenesis (NST, elicited by epinephrine), but did not affect BMR nor the between line divergence in NST measured after acclimation to 4 °C. Likewise, although most studied physiological and behavioral traits (daily energy expenditure, core body temperature, spontaneous locomotor activity, markers of oxidative stress) were affected by ambient temperature, they were not modulated by selection. These patterns, together with the results of our earlier studies on mice divergently selected for BMR, suggest that significant increase in PMR may be not correlated with changes in many other fitness-related traits. Thus, the evolution of high BMR may reflect selection on traits other than PMR (e.g. high sustained metabolic rate during parental care). Financial support: National Science Centre, Poland, grant 2014/15/B/NZ8/00244 for P.B.

83-2 BUCCELLA, LA; FALLOT, K; EATON, K; COFFROTH, MA*; University at Buffalo; *coffroth@buffalo.edu*

Symbiont Composition and Density Change within Three Octocoral Species across a Bleaching Event in the Florida Keys

Coral bleaching (the loss of the algal symbionts) due to increased sea surface temperatures has led to increased mortality of many scleractinians. Although reports of bleaching among octocorals is less common, extensive octocoral bleaching was observed in the Florida Keys during 2014 and 2015. We monitored *Symbiodinium* type and densities in three octocoral species across the 2015 bleaching event (May 2015-May 2016) to investigate severity of bleaching. Individual colonies of *Muricea atlantica*, *Muricea elongata*, and *Plexaurella dichotoma* on two reefs were tagged and cell densities and symbiont type for each species were monitored over the course of the event. Cell densities were significantly different between months, with the lowest densities occurring in September. Based on cell counts, as well as visual observations, *M. atlantica* and *P. dichotoma* colonies were more severely bleached than *Muricea elongata*. Preliminary results indicate that each host species harbored strains within the *Symbiodinium* B1-ITS phylotype. Based on 4 microsatellite loci these species harbor at least 3 (*M. atlantica)* , 9 (*M. elongata*) and 3 (*P. dichotoma*) symbiont genotypes and genotypes were not shared between host-species. Little mortality was observed within any host species through May 2016, and in the majority of corals symbiont genotypes did not change across the bleaching event. These studies are ongoing and additional samples from 2016 and 2017 will be examined to establish a baseline in non-bleaching years. Bleaching tolerance could not be clearly explained by the coral species or the symbiont type independently, and it is possible that both parties play a role in bleaching resistance.

P2-225 BUCHALSKI, B*; SWANSON, B; GUTIERREZ, E; Gonzaga University; *bbuchalski@zagmail.gonzaga.edu*
Population-dependent Variation of Weapon Performance in Rhinoceros Beetles
Sexual selection results in the evolution of exaggerated weapons in some species, but not in others. *Trypoxylus dichotomous,* a species of Rhinoceros Beetle, possesses enormous horns that are used by males in intrasexual combat for reproductive access to females. However, this widespread species shows different horn allometry across populations. We aim to use this natural variation to measure the functional ramifications of horn length variation and to understand the evolution of these exaggerated weapons. We collected force production data in the field for several populations and analyzed the horns as a simple lever system to understand how morphology leads to performance variation. We confirm that horn length allometry varies across populations with upper end differences in horn size varying by 1.4 times from the same sized beetles in other populations. In addition, mechanical advantage and muscle cross-sectional area seem to vary independently. Therefore, the force that horns can produce, an estimate of weapon performance, varies significantly across populations with similarly sized beetles being able to produce 2.1 times the force in different populations. We suggest that both horn length and horn force production may be under differential sexual selection in different populations due to variation in the details of ecology and mating systems.

P1-125 BUMP, P*; LOWE, CJ; Hopkins Marine Station of Stanford University. Pacific Grove, CA.; *paulbump@stanford.edu*
Remodeling and Patterning during Metamorphosis and Regeneration in the Hemichordate Worm Schizocardium californicum
Tissue turnover and remodeling has been an important focus of model system cell and developmental biology. Comparative approaches, mining the amazing diversity of invertebrate body plans, offer unique opportunities to gain insights into key elements of homeostasis and morphogenesis. We propose that the indirect developing enteropneust hemichordate worm *Schizocardium californicum*, with impressive regenerative capability and radical metamorphosis between larva and adult, provides a valuable opportunity for investigating remodeling and patterning during metamorphosis and regeneration. Cell turnover is a fundamental biological progress, a controlled cycle of cell death and cell birth that underlies homeostasis. However, little comparative data has been generated to investigate these key processes in less traditional systems. A window into this process of cell turnover is the metamorphosis of *S. californicum* in which we investigated the balance of proliferation and apoptosis during the dramatic remodeling of pre-existing structures, along with loss and gain of larval-specific and adult-specific traits respectively. The organization of complex body plans remains fascinating, and the remodeling and patterning that occurs during regeneration is an area of ongoing investigation. Regenerative capacities have been observed across the animal kingdom, but head or anterior regeneration had previously been attributed to only protostomes, not deuterostomes. The exception to this has been demonstrated in enteropneust hemichordates. We investigated the balance of proliferation and apoptosis during this process and anticipate that further studies in *S. californicum* will provide insights into the understanding of patterning programs used in anterior regeneration processes.

121-4 BURFORD, BP*; CAREY, NJ; GOLDBOGEN, JA; Hopkins Marine Station of Stanford University; *bburford@stanford.edu*
Does grouping reduce the standard metabolic rates of squid?
Group living is a common feature in many disparate taxa and is known to confer a wide range of advantages including anti-predator defense, enhanced foraging, and reduced costs related to locomotion. As we continue to assess the influence of environmental dynamics on species' physiology, it is important to incorporate essential behaviors, such as grouping, as a part of experimental design in order to arrive at more accurate projections. Squid are ecologically and economically important motile marine predators that demonstrate remarkably high standard metabolic rates and thus are particularly sensitive to environmental variation. Although all squid species whose metabolisms have been examined form groups during most of their lives, all respirometry experiments conducted thus far have been on individual squid, with few attempting to simulate the presence of conspecifics. As has been demonstrated in other ecologically-similar marine animals, it is possible that the standard metabolic rates of squid have been overestimated due to the stress generated from being isolated from conspecifics. We report on the results of a series of respiration experiments where we assessed the difference in standard metabolic rate of California market squid, *Doryteuthis opalescens*, when respired in groups or individually, and discuss how our results compare with metabolic reduction recorded from similar studies in other taxa.

P2-149 BURGAD, AA*; ADAMS, GL; ADAMS, R; University of Central Arkansas ; *aaronburgad@gmail.com*
Patterns of beta diversity and spatial structure of stream fish communities in two stream networks
Spatial patterns of beta diversity (turnover and nestedness) provide insight into how fish communities respond to environmental gradients and human disturbances (e.g. urbanization, and impoundments). Here, we used historical (1977-1982) and current (2016-2017) fish community data from the Saline River basin and Ouachita River basin, Arkansas to examine patterns of beta diversity and spatial structure at three spatial scales: entire river network, mainstem, and tributaries. Specifically, we investigated the increase of pairwise community dissimilarity (i.e. distance decay of similarity) with watercourse distance (rkm). In the Saline River network, we found spatial structure was consistent through time. Overall beta diversity (β_{sor}) and species turnover (β_{sim}) was positively correlated with watercourse distance at all spatial scales and nestedness (β_{nes}) did not correlate with watercourse distance. Species turnover was stronger in tributaries than the mainstem because of high environmental heterogeneity. In the Ouachita River network, we found spatial structure changed through time. Overall beta diversity (β_{sor}) and β_{sim} was lower at all spatial scales during the current period, suggesting the breakdown of regional distinctiveness. Our results show that stream networks influence metacommunity structure, but also demonstrate human disturbances can disrupt natural structuring mechanisms and transform spatial structure in altered stream networks.

59-2 BURGOS, LUIS*; TAYLOR , EMILY; California Polytechnic State University, San Luis Obispo; *lburgos@calpoly.edu*

Effects of Acclimation and Recent Thermal History on the Critical Thermal Maximum of a Small Diurnal Lizard, Sceloporus occidentalis

With temperatures rising globally, researchers are assessing the possible ramifications and impacts of the changing climate. Ectotherms are excellent indicators of potential climactic impacts because of their heavy reliance on the environment for their thermoregulation. Studies have historically looked at thermal maxima to establish predictive models for species extinctions. However, recent findings in marine invertebrates suggest that these thermal maxima, which have been considered as fixed variables, may in fact be plastic and dependent on the organism's recent thermal history. If this is the case, then historical data, literature, and predictive models studying the effects of climate change may not be wholly accurate because so many are based on data from captive lizards that may be acclimated to laboratory conditions. Using a recently described methodology, we tested the critical thermal maximum of the Western fence lizard, *Sceloporus occidentalis*, in all four seasons, both under field and short (two-day) lab-acclimated conditions. We found that there were seasonal differences in each condition, but the differences were not the same between conditions. We also tested three acclimation temperatures during a single seven-day acclimation. The three acclimation temperatures (15C, 25C, and 35C) did not have a significant effect on the critical thermal maximum. However, when comparing thermal maxima, the seven-day acclimation condition had higher values than field condition lizards.

27-2 BURKHARD, TT*; WESTWICK, RR; PHELPS, SM; UT Austin; *ttburk@gmail.com*

Adiposity signals predict song effort in Central American singing mice

All behavior requires energy, but the costs of behavior are particularly conspicuous in the context of animal communication. Animals must invest not only to stand out against a noisy environment, but also to pay the costs of behaviors that follow from communication displays. Much of what we know about the regulation of energy balance, however, comes from rodent models that lack elaborate signals. We develop Alston's singing mouse, Scotinomys teguina - a small diurnal species living in the cloud-forests of Central America - as a model for investigating the relationship between body condition and display effort. We first asked in which dimensions condition varies between male mice, examining a range of circulating nutrients including plasma fatty acids and glucose, metabolic hormones (insulin, adiponectin, leptin), and residual body mass (RBM). Next we asked about the dimensions of variation in male song, examining the number of songs, latency to sing, length of songs, and a variety of measures of amplitude and frequency modulation. Lastly, we asked how well dimensions of condition correlated with dimensions of song effort. We found that measures of adiposity (hormones, RBM) tended to vary independently of circulating nutrients. We found that songs of singing mice differ both in frequency signatures and in "song effort"—measures of temporality and amplitude. We found evidence that song effort is condition-dependent in singing mice. While RBM weakly predicted song effort, adiposity signals (particularly leptin) greatly improved our model. Thus male singing mice seem to adjust song effort as a function of variation in body condition in the field. Refining our understanding of this relationship will allow us to better understand the neuroendocrine mechanisms regulating display effort, and the integrative understanding of animal communication.

5-2 BURNETT, NP*; KOEHL, MAR; Univ. of California, Berkeley; *burnettnp@berkeley.edu*

The Strength of Kelp Tissue Depends on Age, Season, and Herbivore Activity

Kelp in wave-swept coastal areas can be damaged if the mechanical hydrodynamic forces they experience exceed the strength of their tissues, especially if the tissues are already wounded by herbivory. Although wave action and herbivory change seasonally, little is known about how the strength, extensibility (how far it stretches before breaking), and stiffness of of kelp tissues are affected by their age, the season, and herbivore damage. We used fronds of *Egregia menziesii*, a large and abundant intertidal kelp along the coast of western North America, to examine how the mechanical properties of kelp tissue are affected by these factors. Frond tissue became stiffer and stronger as it aged but did not change extensibility. Over a two-year study period, we observed that frond tissue was strongest and stiffest in winter, and weakest and least stiff in summer, but showed no seasonal changes in extensibility. Shifts in frond strength were proportional to seasonal increases in wave action, and inversely proportional to the frond's growth rates. Our study period included an El Niño winter and a non-El Niño winter. Frond tissue was stronger during the non-El Niño winter than during the El Niño winter. Mechanical properties of the frond tissues did not change in response to herbivore damage, although as damaged tissue aged, they became stronger at the same rate as undamaged tissue sections of the frond. In the summer, when waves are small and herbivores are prevalent, the fast growth rates and weak mechanical properties permit the kelp to grow to a large size. In the late fall, growth rates slow and fronds tend to break. Then in winter, the kelp's smaller size, slower growth rates, and stronger mechanical properties allow the kelp to better survive the large hydrodynamic forces of winter storms.

18-6 BURRESS, ED*; TAN, M; University of California, Davis, Emory University; *edb0014@auburn.edu*

Ecological opportunity alters the timing and shape of adaptive radiation

The uneven distribution of diversity is a conspicuous phenomenon across the tree of life. Ecological opportunity is a prominent catalyst of adaptive radiation and therefore may alter patterns of diversification. We evaluated the distribution of shifts in diversification rates across the cichlid phylogeny and the distribution of major clades across phylogenetic space. We also tested if ecological opportunity influenced these patterns. Colonization-associated ecological opportunity altered the tempo and mode of diversification during the adaptive radiation of cichlid fishes. Clades that arose following colonization events diversified faster than other clades. Speciation rate shifts were non-randomly distributed across the phylogeny such that they were disproportionally concentrated around nodes that corresponded with colonization events (i.e., of continents, river basins, or lakes). Young clades tend to expand faster than older clades; however, colonization-associated ecological opportunity accentuated this pattern. There was an interaction between clade age and ecological opportunity that explained the trajectory of clades through phylogenetic space over time. Our results indicate that ecological opportunities afforded by continental- and ecosystem-scale colonization events explain the dramatic speciation rate heterogeneity and phylogenetic imbalance that arose during the evolutionary history of cichlid fishes.

51-6 BURRESS, PBH*; NIEMILLER, ML; CHAKRABARTY, P; Louisiana State University, University of Alabama in Huntsville; *pamelabeth.hart@gmail.com*

Phylogenomics of the Cave-, Spring-, and Swampfishes of North America (Percopsiformes: Amblyopsidae)

Cave-obligate organisms have captured the imagination and interest of scientists and citizens for centuries, yet their complex evolutionary histories and modes of subterranean adaptation are still poorly understood. The North American endemic Amblyopsidae are one of very few ray-finned fish families to contain both surface-dwelling and cave-dwelling members; thus, this group is especially attractive for comparative studies examining subterranean adaptation. Morphological and molecular datasets have presented conflicting evolutionary relationships within the Amblyopsidae, particularly with respect to the placement of eyed genera in relation to the eyeless, cave-obligate taxa. Molecular phylogenies suggest a possible subterranean ancestor for at least one of the eyed genera, implying the re-evolution of eyes and re-colonization of surface habitats. Morphological topologies recover a continuum of forms, progressing from surface to cave-dwelling without re-evolution. To investigate relationships within the Amblyopsidae, we collected genomic data from nearly 2,000 ultraconserved element (UCE) loci. Each of the three states of troglomorphy (surface, cave-facultative, and cave-obligate forms) was included for this study. This work will provide insight into the patterns and modes of cave adaptation.

P3-83 BURTON, EB*; CURRY, RL; Villanova University, Department of Biology; *eburton1@villanova.edu*

Extrapair parentage in a rapidly moving chickadee hybrid zone: confounding factor for analysis of fitness consequences of interbreeding?

In songbirds that hybridize, extrapair parentage may confound analysis of key fitness consequences such as hatching success if the species-level genotypes of extrapair parents differ from those of social parents. Our research on black-capped and Carolina chickadees in southeastern Pennsylvania has revealed rapid northward hybrid zone movement associated with climate change; hatching success has changed correspondingly, with fewer eggs hatching in populations experiencing interbreeding, but whether the patterns are obscured by extrapair parentage is unknown. Using eight species-diagnostic single nucleotide polymorphism (SNP) markers, we genotyped 54 breeders and 137 nestlings from 30 nests over 2 years in one hybrid-zone population (at Hawk Mountain Sanctuary) and conducted parentage analysis to identify extrapair offspring (EPO). At least 30% of nestlings had genotypes that could not be explained by those of their social parents and were therefore EPO, even though species-diagnostic SNPs yield low detection power. Therefore, extrapair mating does potentially confound analysis of hatching success at Hawk Mountain. Work in progress focuses on using these results to refine analysis of hatching success in this hybrid-zone population.

P3-37 BURY, S*; CICHOń, M; BAUCHINGER, U; SADOWSKA, E. T.; Institute of Environmental Sciences, Jagiellonian University; *stanislaw.bury@gmail.com*

Snakes Maintained in Cold Compared to Warm Environment Revealed Higher Oxidative Damage

Aerobic metabolism is assumed to impose costs in terms of production of reactive oxygen species (ROS) through damage to biomolecules. A positive relation between standard metabolic rate (SMR) and ROS production is generally assumed, but recent findings in fish revealed the opposite pattern, a negative relationship. At present, it is still unknown whether the amount of ROS indeed relates to the level of damage and whether environmental factors can affect damage status by affecting energy use. Here we investigated whether acclimation to thermal regimes imposing different SMR causes corresponding variation in damage load and antioxidant capacity in an ectothermic animal, the grass snakes (Natrix natrix). We acclimated 14 snakes for six months to either warm (32oC) or cold (18oC) ambient temperatures before we determined SMR and oxidative status. As expected, warm-acclimated snakes showed higher SMR compared to cold-acclimated ones. Damage load (micronuclei count and dROMs) showed a pattern opposite to SMR, being higher in cold-acclimated snakes. Antioxidant defense was not different between temperatures. Our results corroborate a negative relation between SMR and ROS production and now expand this pattern to the level of damage. Various SMR-dependent mechanisms may contribute to the lower amount of damage. Higher SMR in warm environment reduces the costs in terms of damage to biomolecules and such a link between metabolism and damage could represent the trigger for the evolution of endothermy. Thermogenesis may represent a strategy to cope with high damage stress in cold environment through active elevation of body temperature and associated higher mitochondrial uncoupling.

10-6 BUSTAMANTE, J*; JANKAUSKI, M; DANIEL, TL; University of Washington; *jorgebjr@uw.edu*

Closed loop Monte Carlo models of abdominal contribution to insect flight control

Abdominal actuation during insect flight may contribute to flight control and stability via inertial redirection of flight forces. The abdomen often composes a significant portion of the body mass of an insect and may provide important insight into the possible dual sensor-actuator role of the abdomen for flight control as recently described by the insect wings of the hawkmoth (*Manduca sexta*). An Euler-Lagrange multibody dynamics model was developed to assess the role of the abdomen in horizontal flight for a hawkmoth morphology. The model includes aerodynamic drag of both the abdomen and the head-thorax complex and also lends itself to adjust to other insect morphologies. This model describes the relevant state variables (positions and angles as well as their derivatives) and control variables (average lift vector and abdominal flexion torque) necessary to achieve flight. The model tests the role of the abdomen by (1) increasing and (2) decreasing the torsional stiffness and torsional damping of the abdominal-thoracic joint for (a) horizontal flight, (b) hovering flight and (c) tracking an oscillating flower. Our multibody dynamics model shows that relatively little average motion of the abdomen is associated with flight control in closed loop feedback. However, because flight is inherently pitch unstable, we predict increased variation in the abdomen flexion angle as time ensues.

124-3 BUTLER, A. D.*; EITEL, M; WöRHEIDE , G; CARLSON, S. J.; SPERLING, E. A.; Stanford University , Ludwig-Maximilians-Universität, Munich. , University of California, Davis ; *aodhanb@stanford.edu*

Phylogenomic Analysis of Brachiopoda and Phoronida: Implications for Morphological Evolution, Biomineralization, and the Cambrian Radiation.

Within Lophotrochozoa, brachiopods and allied clades are among the first biomineralized Cambrian metazoans to appear and represent a major component of the oldest known fossil record of animals. While the brachiopod fossil record is ultimately the key to determining character homology and polarity during the evolution of the brachiopod body plan, reading this record has been clouded by disagreement about relationships among the crown clades. Specifically, the monophyly of brachiopods with respect to phoronids, and the relationships of the calcitic to phosphatic-shelled brachiopods. Much of this phylogenetic uncertainty stems from difficulties in rooting the brachiopods and their sister groups within Lophotrochozoa. Phylogenomics—the analysis of hundreds to thousands of orthologous genes in concatenated supermatrices—has been instrumental in resolving difficult phylogenetic relationships in diverse metazoan clades. We have conducted the first such extensive phylogenomic investigation of Brachiopoda/Phoronida with analyses that combine novel sequence data with all publicly available brachiopod and phoronid transcriptomes and a broad range of protostome outgroups. Analyses were run under best fitting evolutionary models (LG amino acid matrix and gamma) utilizing a published 106-gene lophotrochozoan ortholog set. Preliminary results strongly (99% bootstrap) support a monophyletic Brachiopoda with Phoronida as sister group within Lophotrochozoa. Weak support is found for Inarticulata. Investigation of fossil and molecular data in this integrated framework provides novel insight into brachiopod biomineralization and evolutionary patterns during the Cambrian radiation.

13-6 BUTLER, JM*; WHITLOW, SM; MARUSKA, KP; Louisiana State University; *jbutl48@lsu.edu*

Endocrine modulation via sex steroid receptor expression in the eye varies with female ovulation status in the social African cichlid Astatotilapia burtoni

Visual communication is used widely across the animal kingdom to convey crucial information about an animals' identity, motivation, reproductive status, and sex. Although it is well-demonstrated that auditory and olfactory sensitivity can change with reproductive state, fewer studies have tested for plasticity in the visual system, a surprising fact since courtship and mate choice behaviors in many species are largely dependent on visual displays. Here, we tested for reproductive state-dependent plasticity in the peripheral visual system of a cichlid fish by measuring mRNA expression levels of sex steroid receptors in the eyes of ovulated-gravid, non-ovulated-gravid, and mouth brooding females, and dominant and subordinate males. Ovulated females had higher expression of sex steroid receptors than non-ovulated females, but males had similar expression levels independent of reproductive/social state. After inducing ovulation in females with prostaglandin F2α injections, we examined their reproductive behaviors and expression of sex steroid receptors in the eye. PGF2α -injected females were more responsive to male courtship displays, and had higher expression of sex steroid receptors in the eye than vehicle-injected females. In addition, preliminary studies indicate that PFG2α -injected females have increased activation in the retina when exposed to male courtship displays compared to control and vehicle-injected females. Together, these data indicate that plasticity of the peripheral visual system is dependent on female ovulation status, not overall female gravidity, and provides crucial evidence linking endocrine modulation of visual plasticity to mate choice behaviors in females.

P3-136 BUTLER, JM*; WHITLOW, SM; MARUSKA, KP; Louisiana State University; *jbutl48@lsu.edu*

Exposure to Anthropogenic Noise during Mouth Brooding Impacts Maternal Care Behaviors and Juvenile Development in an African Cichlid Fish

Over the last few decades, anthropogenic noise has increased underwater ambient sound levels by >30dB in the range that most fishes detect and produce acoustic signals. Although the impacts of increased background noise on fish development have been studied in a variety of species, there is a paucity of information on how noise affects parental care. Mouth brooding is an energetically costly form of parental care in which the brooding fish carries developing larvae in the buccal cavity for the duration of development. In the African cichlid *Astatotilapia burtoni*, females carry their brood for ~2 weeks during which time she also starves herself. To test the hypothesis that increased background noise impacts maternal care behaviors and brood development, we exposed brooding females to a period of excess noise (~140dB) played through an underwater speaker. Over half of noise-exposed brooding females cannibalized or pre-maturely released their brood, but all silent control females exhibited normal brooding behaviors. Juveniles that were exposed to noise during their brood period had lower growth rates and higher mortality rates than control broods. Further, onset of adult-typical coloration and behaviors was delayed compared to control fish. Because acoustic overstimulation can damage hair-cell based sensory systems, we are currently examining how anthropogenic noise affects development of the lateral line and auditory systems. To our knowledge, this is the first study to examine the impact of excess noise on a mouth brooding fish. As such, these results have important conservation and management implications for protecting against noise-induced effects on maternal care behaviors, development, and ultimately animal survival.

85-6 BUTLER, MA*; RIVERA, JA; SUNG, HW; University of Hawaii; *mbutler@hawaii.edu*

Morphological correlates of jumping and swimming performance in Paupuan microhylid frogs

Semi-aquatic and terrestrial frogs both use the locomotor apparatus (i.e., the hind limb) but can differ greatly in swimming and jumping performance. We conducted a morphological analysis of the hindlimb musculature of two relatively closely related microhylid frogs, which differ in locomotor habit. The semi-aquatic frog, Austrochaperina palmipes is an excellent swimmer and hops on land, often hopping from rock to rock in its stream habitat, whereas the terrestrial frog, Mantophryne laterals is an excellent jumper in its forest understory habitat. We compared muscle architecture, including CSA, pinnation angle, fiber length, muscle length, and muscle moment arm to model forces produced during the jump and correlated it with kinematics of swimming and jumping performance to examine whether there is any design features which explain the variation in performance.

7-6 BUTLER-STRUBEN, H M*; CROOK, R J; San Francisco State University; *hbutlers@mail.sfsu.edu*

Injury Enhances Learning but does not affect Spontaneous Exploratory Behaviors in Cuttlefish

Mammals are typically used to study injury induced behavioral changes, but their convoluted nervous systems make it difficult to examine underlying mechanisms. To advance treatments for humans and animals alike, new models are needed to look at conserved mechanisms of pain. In this study I use the neurologically-complex invertebrate, cuttlefish (Sepia bandensis) to examine the effect of peripheral injury on learning and spontaneous exploration. I hypothesize that, like mammals, cuttlefish exhibit changes to both behaviors in the short term (3h), after experiencing an injury. Furthermore, I hypothesized that injury-induced behavior could be modulated by increasing endogenous serotonin using single, 10nM dose of an SSRI, Fluoxetine. Cuttlefish were fed one shrimp, dosed with Fluoxetine or vehicle, before they received either injury to the tips of feeding tentacles under light sedation, or light sedation with no injury (sham). I used two assays to quantify injury-induced behaviors of cuttlefish; an open-field task that measured spontaneous exploratory behavior, and cognitive task that measures learned inhibition of food capture attempts on inaccessible prey. There were no differences in spontaneous exploratory behaviors between the injured and non-injured groups, however, injured cuttlefish learned more rapidly compared to non-injured cuttlefish. Cuttlefish that received both injury and 10nM of Fluoxetine showed a learning curve more similar to that of non-injured and non-drugged cuttlefish. Unexpectedly, non-injured/drugged cuttlefish had a faster learning curve more closely resembling injured cuttlefish. With these data, I conclude that injury changes cognition, but not spontaneous behavior of cuttlefish, and that there may be other effects of Fluoxetine learning that result in a non-linear interaction with injury.

S1-5 BUTTERFIELD, NJ; University of Cambridge, Cambridge, UK; *njb1005@cam.ac.uk*

Pumping, Swimming and Visual Predation - a Fluid Dynamic View of Early Metazoan Evolution

Animals have an unparalleled capacity to pump and swim through water, but these hydrodynamic properties have been largely overlooked as a factor in early animal evolution. By collectively driving water currents, and compressing corresponding diffusion gradients, even the simplest colonies of flagellated cells gain significant gas-exchange and feeding advantage. These advective effects multiply at larger length scales, particularly in combination with differentiated muscle tissue. At a cnidarian grade of organization, they introduced animals to inertial and turbulent fluid dynamic regimes with negligible metabolic investment. In concert with hydrodynamically tuned morphologies they also led to the phenomenon of swimming, and the metazoan take-over of pelagic ecology. Swimming animals actively mix and ventilate much of the modern oceans as a by-product of their feeding activities. In addition to the repackaging of dispersed surface-generated productivity as sedimenting faecal pellets, a significant fraction is transported actively to depth via diurnal vertical migration (DVM), a behavioural consequence of visual predation, muscular swimming and the size-structured tiering of pelagic food webs. Such activity both aerates the surface ocean and concentrates biological oxygen demand at depth in the form of oxygen minimum zones - independently of atmospheric oxygen concentration or net carbon burial. In this light, it is clear that the depth of DVM and the nature of OMZs must have changed systematically through time, in concert with escalatory innovations in the size and speed and of marine predators. This alone may account for the step-wise changes observed in marine redox signatures through the later Neoproterozoic and early Palaeozoic, as well as intervals experiencing mass extinction.

P1-72 BYRD, AD; CRONIN, TW*; UMBC; *UE80736@umbc.edu*

Effect of Environmental Sand Coloring on Reflectance of Neogonodactylus oerstedii

Mantis shrimp can detect ultraviolet (UV) light, and *Neogonodactylus oerstedii* displays many varying colors and shades. This study was to test if the reflectance of the mantis shrimp species, *N. oerstedii*, changes with the coloring of its environment. To better understand this phenomenon, we placed different individuals in tanks with varying colors of sand on which to live (blue, black, grey, white, a mix of different browns, and a red brown), and weekly reflectance readings were taken on various parts of the body (carapace, thorax, and abdomen) using an Ocean Optics USB-2000 fiber optic spectrometer. Reflectance of the sand was measured using the same instrument at the beginning of the experiment. We repeated this same experimental protocol with animals on white sand but in containers covered by spectrally characterized spectral color filters. Data were analyzed using standard methods. We expected reflectance to change over time to become more like the color they were on or were subjected to via the filters, but after two months of measurements we saw no significant color changes. However, none of the animals had molted since the start of the experiment, so color changes may yet be observed. Current results show that males tend to boost the intensity of their UV reflectance (including shorter wavelength UV) more than females. Animals in neutral/monochromatic colors tended to change less than those in colored ones. Of various body parts, the carapaces tended to stay the most consistent. It will be interesting to see if these trends continue over time.

P2-102 CABRERA, C*; DEBIASSE, M; RYAN, JF; Whitney Laboratory for Marine Bioscience, University of Florida / University of Miami, Whitney Laboratory for Marine Bioscience, University of Florida; *cabreraclau96@gmail.com*

Reanalyses of sponge homeobox genes suggest Hox and ParaHox genes arose after sponges diverged from other animals.

Hox and ParaHox genes are highly conserved animal-specific transcription factors that pattern the primary body axis during embryogenesis. Until recently, it was thought that sponges, a lineage that branched off early in animal evolution, lacked Hox and ParaHox genes, which would indicate that these genes originated relatively recently in evolution. However, a 2014 study identified ParaHox genes (Cdx) in two calcareous sponge species, putting this long-held doctrine into question. A closer look at these findings led us to the hypothesis that the results of this study are heavily dependent on the distance-based phylogenetic methods employed, which are sensitive to long-branch attraction artifacts, as well as the limited taxon sampling employed. To test this hypothesis, we reanalyzed the original datasets with multiple methods and also analyzed a new dataset that included a more diverse set of taxa. All but one of our maximum-likelihood (ML) and Bayesian analyses suggest that the two reported calcareous sponge genes are not ParaHox genes, but rather belong to the NKL subclass homeoboxes. Similarly, neighbor-joining analyses of our more diverse dataset yielded the same conclusion. Based on these results, we assert that the previous evidence suggesting the presence of Hox/ParaHox genes in sponges is reliant on distance-based methodology and the taxon sampling employed in the original study. Our new results suggest that Hox and ParaHox genes arose after sponges diverged from the rest of animals.

3-1 CADE, DE*; FRIEDLAENDER, AS; CALAMBOKIDIS, J; CAREY, N; DOMENICI, P; POTVIN, J; GOLDBOGEN, JA; Hopkins Marine Station, Stanford University, Marine Mammal Institute, Oregon State University, Cascadia Research Collective, CNR-IAMC-Unita Operativa di Oristano; *davecade@stanford.edu*

Predator-Prey Dynamics and Kinematics of Rorqual Whales and Their Prey

Locomotion and feeding are integrated in many aquatic vertebrates, and the behavioral plasticity of these connected systems may reflect broad-scale functional and evolutionary responses to ecological dynamics. Predator-prey interactions may require the optimization of, or sufficient performance in, maneuverability, coordination, and prey capture speed. We used video and movement sensor tags to quantify the body and skull kinematics during feeding events in rorqual whales, a family of baleen whales that exhibit an extreme lunge filter feeding mechanism. Lunge feeding consists of an acceleration to high speed and engulfment of a large volume of prey-laden water, however, despite previous assumptions the kinematics of lunge feeding were not conserved. While krill-feeding blue and humpback whales exhibited temporally distinct acceleration and engulfment phases, humpback whales pursuing more agile prey (i.e. anchovies) demonstrated highly variable coordination of skull and body kinematics in the context of complex prey-herding techniques. Despite pursuing faster prey, fish-feeding humpbacks often fed at slower speeds than krill-feeding humpbacks. Escape response experiments on anchovies startled by a looming stimulus parameterized with tag data suggest that whale speed has less of an effect on prey escape responses than the timing of the mouth opening and the rapid increase in projected body area. Our results have important implications for understanding the mechanisms and behavioral strategies large predators use to capture different prey. Moreover, these studies help inform the dynamics that govern energy flux through filter feeders in coastal upwelling ecosystems.

53-6 CADNEY, MD*; HIRAMATSU, L; THOMPSON, Z; ZHAO, M; KAY, JC; SINGLETON, JM; ALBUQUERQUE, RL; SCHMILL, MP; GARLAND, JR., T; Univ. of California, Riverside; *mcadney@gmail.com*

Effects of Early-Life Exposure to Western Diet and Voluntary Exercise on Adult Activity Levels, Exercise Physiology, and Associated Traits in Mice

Locomotor activity is a key element of most animal behaviors. Individual variation in the amount of voluntary exercise (VE) and spontaneous physical activity (SPA), in both humans and laboratory rodents, is known to be heritable, but also affected by numerous environmental factors. Early-life experiences that may have long-lasting effects are one potentially important aspect of environmental factors. The current experiment was designed to explore genetic, environmental, and early-life effects in the context of a long-term selection experiment that includes 4 lines of high runner (HR) mice, selectively bred for >75 generations for voluntary wheel-running as young adults, as well as their 4 non-selected control lines. In the present experiment, we altered VE by granting wheel access or not and administered either standard or Western diet (WD) during the juvenile period from weaning to 6 weeks of age (sexual maturity), followed by housing without wheels and with standard chow. ~2 months later, we measured wheel-running behavior (VE), home-cage activity (SPA), and several potentially related physiological and behavioral traits. As adults, HR mice ran more than C regardless of treatment, but linetype also had statistically significant interactions with both early-life wheel access and diet. For example, juvenile wheel access increased adult VE for C mice, but deceased it for HR, whereas juvenile WD increased adult VE for HR but not for C mice. Juvenile wheel access decreased adult relative heart mass, but increased relative triceps surae muscle mass, fat mass, and blood [glucose]. These and other results demonstrate that both juvenile exercise environment and diet can have long-lasting effects on adult activity behaviors and related phenotypes.

P1-17 CAGGIANO , EG*; CERIO , DG; PORTER, WR; RIDGELY, RC; WITMER, LM; Ohio Univ.; *ec884814@ohio.edu*

Avian nasal salt glands: anatomy and its relevance for inferring the behavior and habitat preferences of extinct birds

The kidneys of extant sauropsids (birds, crocs, squamates, etc.) tend to be less efficient at removing excess salt from the blood, and sites of extrarenal salt excretion are common, such as the nasal gland in birds. The physiology of the hypertrophied nasal salt glands of many marine birds is well-understood, but the anatomy is poorly documented. We present the results of our survey of avian nasal gland structure to better resolve the osteological correlates (OCs) of the gland, its ducts, and its vascular supply. The resulting OCs allow an assessment of the presence, position, and size of the nasal gland in extinct birds, allowing rough assessments of salt loads and hence habitat preferences (e.g., marine vs. terrestrial). The extant studies emphasize marine and aquatic birds (e.g., albatrosses, gulls, cormorants, anseriforms) as well as non-marine outgroups (e.g., ostrich), drawing on (1) gross dissection, (2) diceCT and spiceCT (iodine enhanced microCT), and (3) radio-opaque vascular injection followed by microCT. These studies provide not only detailed anatomical information, but also permit quantification of gland volumes for comparative analysis. These extant studies shed new light on the interpretation of the nasal glands of extinct birds, such as the Cretaceous marine toothed birds *Hesperornis* and *Ichthyornis*. The flightless diver *Hesperornis* had enormous nasal glands, suggesting that it was forced to consume seawater, whereas the volant *Ichthyornis* had smaller salt glands suggesting that it perhaps also had access to fresh water sources. The Paleogene anseriform bird *Presbyornis*, typically regarded as inhabiting saline soda lakes, also was sampled and provides new evidence for a modest nasal salt gland.

P1-131 CAHILL, AE*; CHENUIL, A; Albion College, Aix Marseille Univ, Avignon Université, CNRS, IRD, IMBE, Station Marine d'Endoume; *acahill@albion.edu*

Cryptic species in the marine environment: a review of the evidence and a way forward

Cryptic species are species that have been demonstrated to be reproductively isolated units but belong to the same nominal species. The use of genetic markers has led to a dramatic rise in the discovery and description of cryptic species in recent decades, and the marine environment is no exception. The correct identification of cryptic species is important for conservation and biodiversity monitoring, among other applications, so we set out to understand the patterns of described cryptic species in the marine literature. A systematic review in Web of Science identified over 600 described cases of cryptic species among marine metazoans. We carried out further analysis to test hypotheses including which phyla were more likely to contain reported cryptic species, whether or not the occurrence of cryptic species is related to geography or habitat, ease of sampling, etc. Furthermore, we developed a classification of cryptic species based on levels of both morphological differentiation and reproductive isolation. This allowed us to identify the cases of cryptic species in the literature that are truly cryptic (i.e. morphologically identical), versus morphologically differentiated species in need of taxonomic revision. Our results will allow for further hypothesis testing to estimate the consequences of cryptic species on biodiversity indices or other metrics.

P1-60 CAIN, SD*; HAYS-WEHLE, E; HOFFMAN, G; Whitman College, Eastern Oregon University, Whitman College; *shaun.cain@eou.edu*

A Morphological and Immunohistochemical Study of the Foot of the Pond Snail Lymnaea stagnalis

Most gastropod molluscs use their foot to locomote, despite differences in the substrate over which they crawl. Little, however, is known about the morphological and neural structures of the foot and how it promotes locomotion. The pond snail, *Lymnaea stagnalis*, is a freshwater gastropod that employs both muscular and ciliary waves during crawling. Here we investigated the morphological characteristics of *L. stagnalis* foot tissue as well as the distribution of neurotransmitters previously found to be involved in ciliary locomotory behavior. To determine the structure of the foot tissue we used histological methods to differentiate tissue and cell type distributions, including both muscles and mucus secreting cells. In addition, we used immunohistological techniques to determine the distribution of putative neuro-active molecules (5-HT, Dopamine, NO, GABA) in the foot tissue. Preliminary results showed both extensive subdermal musculature, and cells involved in mucus production. These findings, combined with the immunohistochemical labeling, will provide a better understanding of the control of crawling in gastropods.

103-2 CAMACHO, J*; TABIN, CJ; ABZHANOV, A; Harvard University, Harvard Medical School, Imperial College London; *jcamacho@fas.harvard.edu*

Exploring adaptive and novel traits of bat faces through morphometrics and developmental genetics

The New World leaf-nosed bats (phyllostomids) display exemplary morphological adaptations associated with specialized modes of feeding. Phyllostomid bat skulls underwent significant alteration, most notably in the cranial base, cranial vault, and the length of the face. These changes, among others, occurred over a very short evolutionary interval, which brings into focus underlying developmental mechanisms behind those changes. Despite the wealth of studies into bat evolution virtually nothing is understood about the developmental events responsible for the emergence of cranial diversity. In this study, we describe, quantify and compare cranial neural crest cell (cNCC) dynamics and signaling molecules required for cartilage and bone development in the evolution and development of the upper face and anterior cranial base. Interestingly, the novel facial structure of phyllostomids (leaf-nose), which is related to their mode of echolocation, may result from an expansion in a subset of cNCC surrounding the anterior dorsal nasal cartilage. Significant gene expression and protein level changes in BMP during skeletal differentiation and growth between key bat species provide the foundation for testing hypothesis about the link between ontogeny and phylogeny. Specifically, gene expression may be experimentally replicated in the mouse embryo cNCC and subsequent phenotype examined to evaluate if evolutionary patterns are mimicked. This will reveal causative connection between morphological and molecular changes.

P3-174 CAMARILLO, H*; TOBLER, M; Kansas State University; *hcamaril@ksu.edu*

Functional Consequences of Morphological Variation in Sulfide Spring Fishes

Natural selection drives the evolution of traits to optimize organismal performance in the context of their environment. However, optimization of one trait or function may adversely impact the expression of other traits and functions, and complex phenotypes inadvertently represent a comprise of balancing different needs. Functional trade-offs can consequently impact evolutionary outcomes and influence phenotypic variation along environmental gradients. We tested how morphological variation of fish along a natural toxicity gradient impacts organismal function in terms of locomotion and ventilation. Several lineages of *Poecilia mexicana* (Poeciliidae) have colonized toxic, hydrogen sulfide rich springs. Adjacent populations in sulfide springs and regular stream habitats face strong and multifarious divergent selection from abiotic and biotic environmental conditions. For example, fish in sulfide springs are exposed to high toxicity and hypoxia, high levels of intra-specific competition and relatively few aquatic predators. In contrast, fish inhabiting normal freshwater streams are exposed to higher levels of oxygen and more complex communities (higher levels of inter-specific competition and predation). We quantified variation in morphology and used high-speed videography to quantify different performance metrics in individual fish from sulfidic and non-sulfidic populations, including aspects of burst speed, steady swimming, and gill ventilation capacity. Data are used to test for correlations between specific morphological traits and aspects of swimming and ventilation performance as well as for trade-offs between different modes of swimming and oxygen acquisition.

71-5 CAMPBELL, JB*; ANDERSEN, MK; OVERGAARD, J; HARRISON, JF; Arizona State University, Aarhus University; *jacob.campbell.1@asu.edu*

Non-conventional anoxia tolerance: adult Drosophila outlive larvae despite inferior ATP and hemolymph [K"+"] maintenance

Oxygen limitation plays a key role in many pathologies, and yet we still lack a fundamental understanding of the mechanisms responsible for intra- and interspecific variation in hypoxia/anoxia tolerance. Current theory suggests that a better anoxia tolerance primarily involves the ability to maintain cellular energetic status as depletion of ATP leads to detrimental processes (e.g. disruption of ionic homeostasis, depolarization of membranes). In this study, we tested for possible mechanisms that allow *Drosophila melanogaster* adults to survive longer periods of anoxia than third instar larvae (LT50: ~8 vs. 1 h). During the first two hours, larval ATP fell to <1% of normal and [K^+] rose by 50%; survival fell to zero in strong correlation with ATP and [K^+]. In adults, during the first two hours, ATP to fell to 2% of normal values, [K^+] rose by ~3x, but survival was 100%. During the next six hours, adults maintained high survival, while ATP was maintained at 2% of normal levels, and hemolymph [K^+] continued to rise to 5x normal. Over 8 h of anoxia, adults quickly restored hemolymph [K^+] if returned to normoxia, despite having hemolymph [K^+] levels up to 4.5x greater than resting. In adults exposed to more than 8 h of anoxia, ATP levels decreased further and [K^+] continued to rise; both of these variables correlated with decreased survival. The superior anoxia tolerance of adult *Drosophila* appears to be due to the capacity to maintain and tolerate very low ATP levels, and to the ability to tolerate high extracellular [K^+]. This study suggests that a new focus of research in anoxia-tolerance should be the mechanisms by which animals can survive and quickly recover from such energetic and ionic conditions. Supported by NSF IOS1256745.

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Evolution of Hemorrhagic Potential in Arenaviridae: A Bioinformatics Analysis of Old and New World Arenaviruses

Considering recent interest in hemorrhagic fevers due to outbreaks of the Filovirus *Ebolavirus*, bioinformatic analyses tracing the origin and evolution of hemorrhagic potential in Arenaviruses has interesting implications. This project aimed to (a) perform full phylogenetic analysis of known Arenaviruses utilizing both entire genomes and portions of the genomes and (b) search for the origins of hemorrhagic potential within the hemorrhagic strains and/or the loss of hemorrhagic potential within non-hemorrhagic strains. The results of this project clarify the relationships between and evolution of a family of viruses which are poorly organized. The pathogenicity of many of these viruses is unclear, but this project shows that *Lujo*, one of only two verified hemorrhagic Old World Arenavirus, is a likely relative of the virus responsible for the Old World to New World transition. In addition, the placement of New World hemorrhagic strains on the phylogenetic tree may indicate that the non-hemorrhagic strains experienced a loss of function event. This project will discuss the identification and tracking of genetic traits which allow viruses to create hemorrhagic disease in humans, possibly providing further insight into potential molecular causes of viral hemorrhagic potential.

90-5 CAMPBELL-STATON, SC*; WINCHELL, K; University of Montana, Missoula, University of Massachusetts, Boston; *shane.campbellstaton@gmail.com*

Temperature-mediated shifts in performance and gene expression between populations of the Puerto Rican crested anole in natural and urban habitats

Human-mediated environmental change is having profound impacts on ecosystems across the globe. For example, urbanization creates local environments that are hotter than surrounding natural areas (urban heat island effect). Urban warming likely has widespread biological consequences, affecting temporal patterns of growth, survival and reproduction. Therefore, urban heat islands may provide a unique opportunity to explore how organisms respond to anthropogenic change. However, our understanding of biological response to these extreme environments is limited. In this study, we explore in situ divergence in thermal tolerance and gene expression between urban and natural populations of the crested anole across the island of Puerto Rico. We use common garden experiments to examine the contributions of adult flexibility, developmental plasticity and constitutive genetically-based differences to observed performance and regulatory divergence observed in situ. Lastly, we use transcriptome scans to search for evidence of temperature-induced selection in urban heat islands. Together, these data provide a comprehensive investigation of the biological effects of urban heat islands on thermal physiology of ectothermic species.

P2-162 CAMPER, BT*; CUTTINO, LA; CARLO, MA; SEARS, MW; Clemson University; *bcamper@g.clemson.edu*

Geographic variation in acclimatory capacity of embryos in response to changing nest temperatures

Organisms in sessile life stages rely heavily on physiological plasticity to buffer the effects of thermal stressors. However, local adaptation may constrain the capacity for acclimation to changing thermal conditions. The widespread lizard *Sceloporus undulatus* lays eggs in shallow nests where embryos experience daily temperature fluctuations. Recently, we found that nesting behavior varies across latitudes such that *S. undulatus* embryos from warmer southern latitudes experience cooler thermal regimes than northern embryos. Embryos from northern populations grow and develop more quickly than southern embryos, even when reared under the same temperatures, a pattern which could have been driven by geographic variation in nesting behavior. Adaptation of embryo physiology to variation in nesting conditions along latitudinal clines could constrain the capacity for acclimation to changing thermal conditions. Here, we performed reciprocal transplants of eggs from three populations across a latitudinal gradient to examine variation in plasticity of embryonic cardiac performance in response to nest thermal regimes. For the first six weeks of incubation, we measured embryonic heart rates across temperatures at two-hour intervals between the daily minimum and maximum temperatures in each treatment. We then calculated the Q10 and energy of activation of heart rate during each week to compare the capacity for acclimation to changing nest temperatures across geography. Our results will demonstrate how local adaptation of maternal behavior and embryonic physiology may interact to affect thermal acclimatory capacity. Geographic variation in the physiological plasticity of widespread ectotherms during sessile stages of development has significant implications for the ability to buffer negative effects of climate warming.

42-4 CAMPOS, SM*; PRUETT, JA; SOINI, HA; NOVOTNY, MV; ZúñIGA-VEGA, JJ; VITAL-GARCíA, C; HEWS, DK; MARTINS, EP; Indiana University, Bloomington, Indiana State University, Universidad Nacional Autónoma de México, Universidad Autónoma de Ciudad Juárez, Arizona State University; *smcampos@indiana.edu*

Relationships between climate, chemical signal composition, and behavior

Many signals used in animal communication are shaped by natural and sexual selection imposed by characteristics of the physical habitat and receiver sensory systems, and retain little trace of phylogenetic similarity. Specific compounds may contribute to chemical signals directly, be metabolic byproducts or have some combination of these and other functions. To explore the functions of specific compounds and the chemical classes they belong to we used a genus of lizards that exploit a diverse array of habitat types. We compared the composition of chemical signals from twelve species of *Sceloporus* lizards, using gas chromatography-mass spectrometry (GC-MS) to characterize secretions and modern phylogenetic comparative methods to infer the relative importance of phylogenetic history, temperature and precipitation in signal composition. We also asked whether composition reflects rates of chemosensory behavior. Fatty acids were the most abundant class of compounds. We found that habitat temperature was negatively correlated to the proportion of unsaturated fatty acids comprising species' chemical signals. Rates of chemosensory behavior were positively correlated to the proportion of saturated fatty acids. We discuss the link between compound abundance and species habitat, phylogenetic history, and chemical behavior.

P2-81 CANNEDY, JP*; WATSON, CM; SHIPLEY, M; Midwestern State University; *jpcannedy0330@my.mwsu.edu*

The effects of nicotine concentration on the physiology and performance of the tobacco hornworm, Manduca sexta

Tobacco employs the chemical nicotine as a method to deter defoliation by herbivores. Some species, such as the Tobacco Hornworm, *Manduca sexta*, tolerates the noxious chemical and specializes upon these toxic plants. This caterpillar is a significant crop pest and is the subject of constant eradication efforts by farmers. While we know that *M. sexta* mostly passes the nicotine in feces and does not incorporate much (if any) of the noxious chemical into its own tissues, the effects of increased nicotine concentrations on its physiology and performance is generally unknown. In our study, we report differences in growth rate, digestive efficiency, metabolic rate, and performance of *M. sexta* being fed different concentrations of nicotine in commercially-available caterpillar food. Our findings suggest that the tobacco plant can negatively impact hornworm physiology by producing more nicotine. Future complementary field studies may reveal the extent that tobacco plant can upregulate nicotine production and what levels are effective *in situ*. This laboratory investigation provides a better understanding of *M. sexta* physiology and its relationship with *Nicotiana tabacum*.

P2-110 CANNON, JT*; KINGSTON, ACN; KOCOT, KM; EERNISSE, DJ; OAKLEY, TH; SPEISER, DI; University of California, Santa Barbara, University of South Carolina, University of Alabama, California State University, Fullerton; *johanna.cannon@lifesci.ucsb.edu*

Phylogenomic evidence that chiton "shell eyes" may have recently evolved from shell eyespots

Chitons (Mollusca: Polyplacophora) have eight overlapping shell plates; these contain clusters of sensory cells called aesthetes. In some chiton species, aesthetes are modified to include an eyespot, and in others, aesthetes are present in addition to eyes with a lens and retina. To address the evolution of complexity in chiton eyes, it is necessary to phylogenetically test whether Chitoninae, with eyespots, is sister to Acanthopleurinae + Toniciinae, with lens eyes. To this end, we have taken a phylogenomic approach using transcriptome data. We sequenced cDNA from sixteen chiton species and one aplacophoran with Illumina Hi-Seq. In addition to novel aculiferan data sequenced for this study, we included data from ten species available on SRA, and data from three mollusc genomes. Our final data matrix contains 30 mollusc species and >500 genes. Overall, our phylogenomic results are consistent with previously published chiton phylogenies, with major lineages supported as monophyletic. Chitoninae is sister to Acanthopleurinae + Toniciinae in our analyses, suggesting that eyespots may be the morphological precursors of ‘shell eyes'. However, expanded taxon sampling is needed to address remaining questions. To generate a more taxon-rich phylogeny for Chitonina, we have used our transcriptome-based data matrix to design probes for a genomic-DNA targeted gene capture study. This target-capture study will enable us to more directly address the question of whether or not lens eyes have multiple origins in chitons.

94-6 CAPLINS, S/A; University of California, Davis; *sacaplins@ucdavis.edu*

Individual Plasticity for Larval Type in a Sea Slug

Marine invertebrates exhibit astonishing levels of morphological diversity in their adult forms. Their larvae, however, can be broadly grouped into a few developmental modes defined by how they acquire the nutrients they need to reach adulthood. While most species are fixed for developmental mode, there are a handful of species that are dimorphic, producing both lecithotrophic (yolk-feeding) and planktrophic (plankton-feeding) larvae. These dimorphic species allow detailed investigations into the genetic and environmental factors underlying the evolution of larval type, unhindered by additional cross-species differences. The species *Alderia willowi*, is plastic for larval type. Larval type in *A. willowi* is influenced by season, with more lecithotrophic larvae produced in summer and more planktotrophic larvae in winter. I examined individual plasticity for larval type in *A. willowi* by subjecting lab reared individuals to changes in salinity and temperature. I chose salinity and temperature that mimic mean summer (20 °C, 32ppt) and winter (16 °C, 16ppt) conditions. I found a great deal of variation in individual plasticity that was not subject to an overall family-level response. I raised several lines of self-fertilized offspring to examine the effect of reduced genetic diversity on individual response to environment. These lines were exposed to changes in salinity and temperature and monitored for larval type. These results suggest a G X E interaction that involves multiple small effect genes. From these inbred lines I have selected individuals that have crossing-reaction norms, and will use these lines to form F2 mapping population. These mapping populations will allow me to identify the number and location of genes involved in larval type in *A. willowi*.

P1-18 CAPSHAW, G*; SOARES, D; CARR, CE; University of Maryland, College Park, New Jersey Institute of Technology; *gcapshaw@umd.edu*

A comparative analysis of phylogenetic and ecological trends in variation of salamander inner ear morphology

The amphibian ear is highly sensitive to both air and water-borne sound energy and substrate-borne vibration. In anurans, auditory sensitivity on land is facilitated by an impedance matching tympanic middle ear. Salamanders lack many of the structural adaptations that enhance perception of airborne sound, including the tympanum and the middle ear cavity. However, early anatomical work has revealed much structural diversity in the salamander auditory system. The function of this diversity remains unresolved, but may have significant implications for hearing abilities across species. In this study, we use a comparative morphometric approach to explore the relationship between structural variation in the otic region, phylogenetic relatedness, and ecological diversification in salamanders. We contrast cave-adapted lineages with closely related terrestrial and aquatic surface species in order to sample species that experience variation in the physical constraints imposed by the environment on their sensory systems. We hypothesize that cave-related auditory variation will include structural changes to the otic region to support increased sensitivity to acoustic energy (in the form of sound and vibration), including hypertrophy of the inner ear organs and/or greater coupling of otic structures to the fluid of the inner ear. Preliminary results reveal trends in otic variation among cave-adapted lineages of salamanders, including an enlargement of the perilymphatic foramina, which may have physiological consequences for the fluid pressure relief pathway of the inner ear, and for potential directionality of the coupled ears.

29-5 CARLO, MA*; CUTTINO, LA; CAMPER, BT; SEARS, MW; Clemson University; *mcarlo@clemson.edu*

Plasticity of nesting behavior and embryo physiology interact as drivers of phenotypic variation in a widespread ectotherm

Despite the prevalence of phenotypic variation in natural environments, we lack the understanding to explain why certain patterns arise along environmental gradients. For species with complex life cycles, adaptive responses to the local environment may be necessary throughout ontogeny since different life stages often occupy different microhabitats. Sessile stages of development are particularly sensitive to changing conditions due to limited behavioral capacities and the small range of microclimatic conditions experienced over small spatial extents (e.g., an egg). Therefore, plasticity in maternal behavior and in the physiology of immobile life stages may be key factors underlying phenotypic variation in some widespread species. To investigate how nesting behavior and embryo physiology may underlie phenotypic variation across the range of a widespread North American lizard, *Sceloporus undulatus*, we examined responses of mobile and immobile life stages to variation in the thermal environment along a latitudinal cline. First, we compared nesting behavior and nest thermal profiles between the southern and northern reaches of the *S. undulatus* range. We found that northern females nest in open areas at forest edges while southern females nest at shadier sites. Thus, embryos at hotter southern latitudes experience cooler thermal regimes than their northern conspecifics. We then performed a reciprocal transplant experiment rearing embryos from the northern and southern locations in the laboratory under treatments simulating nest temperatures at those sites. Our results will show how variation in nesting behavior and embryo thermal physiology may contribute to patterns of phenotypic variation across the species range.

P1-288 CARLOWICZ, RM*; MORAN, CM; GERRY, SP; Fairfield University; *rachel.carlowicz@student.fairfield.edu*

Temperature effects on feeding kinematics in cunner, a hibernating labrid fish

Cunner (*Tautogolabrus adspersus*) are a temperate labrid that can be found along the coast of Northeastern North America from Virginia to Nova Scotia. During winter, cunner enter a state of extended torpor in order to conserve energy. In cunner, locomotor muscle function and performance is inhibited when temperatures drop below 10 ^{o}C. To further understand the effects of temperature on ecologically relevant tasks, we asked, how is feeding activity influenced by a decrease in temperature? Our study investigated the feeding kinematics of cunner at varying temperatures (20 ^{o}C, 15 ^{o}C, 10 ^{o}C, 5 ^{o}C). We hypothesized that the kinematic variables would be slower at lower temperatures. Seven cunner were fed pieces of sandworm and Asian shore crabs. For each individual, we recorded three feeding events for each prey type at 500 frames s^{-1}. We analyzed: gape, gape velocity, ram, ram velocity, time to prey capture, prey velocity, and distance to prey at mouth opening. Contrary to our hypothesis, no differences in feeding behaviors were observed. Ten ^{o}C is the upper limit of the cunner hibernation temperature range, therefore, jaw muscle activity might not be inhibited at this temperature. Further experimentation may yield significant differences in cunner acclimated at 5 ^{o}C. If there are no differences in temperature after further experimentation, it is possible that cunner muscles are highly adaptable and that their feeding behavior would not be altered by drastic changes in temperature.

S1-11 CARON, Jean-Bernard; Royal Ontario Museum, Canada; *jcaron@rom.on.ca*

The Origin of Phyla—Insights From the Burgess Shale

The iconic 508 million-year-old Burgess Shale, famous for its exceptional preservation of a diverse community of soft-bodied marine organisms, was key to defining the concept of the Cambrian Explosion as a true biological event, but the interpretation of many of its constituent taxa has had a checkered history. In particular, the role of a number of so-called Problematica in reconstructing early animal evolution has traditionally been difficult to assess. New field discoveries and continuous research have allowed for the revision of many of these problematic forms as stem groups of known clades, including modern phyla, although many questions remain. In this talk, I will provide a survey of recent progress in our understanding of the affinities of several key taxa, in particular, those related to the early evolution of panarthropods.

P1-239 CARP, SB*; TAYLOR, JH; FRENCH, JA; University of Nebraska at Omaha; *scarp@unomaha.edu*

Differential Effects of Receptor-Specific Dopamine Treatment on Short and Long-Term Marmoset Pairs

The monoamine neurotransmitter dopamine (DA) has roles in both reward and social behavior, and is a potential mediator through which social interactions are perceived as rewarding. Subfamilies of DA receptors (D1 and D2) differentially modulate specific behaviors underlying pair bonding in monogamous rodents, but have not been systematically examined in nonhuman primates. D1 and D2 receptor agonists and antagonists were administered to pair-living marmosets in either short term (n=7 pairs, average < .5 yrs.) or long-term (n=5 pairs, average > 2 yrs.) pairs. Subjects were tested using a partner preference paradigm in which access to both the pair mate and an unfamiliar opposite-sex conspecific was available. Affiliative and agonistic behaviors toward both stimulus animals were recorded. Under saline conditions, long-term pairs spent significantly more time with their pair-mate than the stranger, $F(1,8)=5.60$, $p=.045$, while short-term pair did not display a preference for either stimulus animal, $F(1,12)=0.50$, $p=.492$). Marmosets in short-term pairs treated with either a D1 ($p=.008$) or D2 ($p=.027$) receptor antagonist displayed reduced sexual solicitations to a stranger, while treatment with a D1 receptor agonist ($p=.034$) increased sexual solicitations to a stranger, compared to when treated with saline. DA treatment had no effect on sexual solicitations for members of long-term pairs. Marmosets in long-term pairs that were treated with a D2 agonist displayed reduced overall time spent in close proximity to either stimulus animal, $F(4,28)=3.07$, $p=.032$. However, this effect on proximity was not observed in short-term pairs, $F(8,104)=1.79$, $p=.086$. These findings suggest that the DA system plays a role in regulating social interactions between current or potential mating partners.

P2-219 CARR, J A*; SULLIVAN, C M; TYTELL, E D; Salem State University, Emmanuel College, Tufts University; *jennifer.carr@tufts.edu*

Twitch Kinetics as a Function of the Length-Tension Relationship of Skeletal Muscle

Intrinsic muscle properties such as force-velocity and length-tension effects are often used in musculoskelatal modelling and are important when considering muscle function in vivo. Several research studies have examined how muscle length affects the influx of calcium into the muscle during isotonic twitches but no one has examined how length affects the kinetics of the twitch in terms of timing and force development. My research examines the effects of length on the kinetics of force development in skeletal muscle across the length-tension curve. We measured the force of single twitches in isolated muscle preparations from the silver lamprey (*Ichthyomyzon unicuspis*) to quantify the length-tension curve, starting at the ascending limb, proceeding through past optimal length, and onto the descending limb. From each of the twitches, the force produced by the muscle and the timing of various points relative to the stimulus was measured. During muscle contraction and relaxation we measured the time that the muscle reached 50%, 90%, and 100% maximal force and then relaxed to 50% and 90% relaxation. From these data the average rate of force development and decay were calculated at different times within the twitch. In addition, the instantaneous rate of force development and relaxation were examined to see the effects of length throughout the twitch. Our results suggest that the rate of force development during contraction is constant up to 50% of maximal force, but the rate of force development from 50% to maximal force increases as the length increases. Our results suggest that the twitch response of skeletal muscle depends on length and other considerations may have to be considered when determining the effect of length on force production.

122-4 CARRIER, D/R*; CUNNINGHAM, C; University of Utah, Swansea University; *carrier@biology.utah.edu*

The effect of foot posture on capacity to apply free moments to the ground: implications for fighting performance in great apes

In contrast to most other primates, great apes have feet in which the heel supports body weight during standing, walking, and running. One possible advantage of this "plantigrade" foot posture is that it may enhance fighting performance by increasing the ability to apply free moments (i.e., force couples) to the ground. We tested this possibility by measuring performance of human subjects when performing from plantigrade and digitigrade (standing on the ball of the foot and toes) postures. We found that plantigrade posture substantially increased the capacity to apply free moments to the ground and to perform a variety of behaviors that are likely to be important to fighting performance in great apes. As predicted, performance in maximal effort lateral striking and pushing was strongly correlated with free moment magnitude. All else being equal, these results suggest species that can adopt plantigrade posture will be able to apply larger free moments to the ground than species restricted to digitigrade or unguligrade foot posture. Additionally, these results are consistent with the suggestion that selection for physical competition may have been one of the factors that led to the evolution of the derived plantigrade foot posture of great apes.

64-6 CARRILLO-BALTODANO, A*; MEYER, N; Clark University; *acarrillobaltodano@clarku.edu*

Decoupling Brain from Nerve Cord Development in the Annelid Capitella teleta

Neural development often starts with a region of ectoderm receiving extrinsic signals instructing it to become neural. Our understanding of nervous system development largely comes from studies within Deuterostomia and Ecdysozoa, and less so from the third major bilaterian clade, Spiralia. Studying how nervous systems develop in different animal groups will help us reconstruct how they evolved. To investigate whether intrinsic or extrinsic signals are involved in early neural specification in a spiralian, we isolated embryonic blastomeres from the annelid *Capitella teleta*. After six days, daughters of isolated 1st-quartet micromeres, fated to form the episphere including the brain, expressed the pan-neuronal gene *Ct-elav1*, indicating a possible role for lineage-specific neural determinants in brain formation. Isolated 2d micromeres, fated to form the trunk ectoderm and ventral nerve cord (VNC) did not survive. However, when the 2d micromere was isolated with other micromeres, larvae developed an elongated trunk and episphere, with *Ct-elav1* expressed exclusively within the episphere. These results show that 2d requires extrinsic signals from the 2nd-quartet macromeres or their descendants, which generate the mesoderm and endoderm, to specify the VNC. We propose that autonomous specification of anterior neural ectoderm evolved in spiralians, enabling the swimming larvae to respond quickly to environmental cues. In contrast, multiple signaling pathways could have been co-opted to conditionally specify the VNC. Future experiments will examine the transcriptomic profile of isolated blastomeres to identify putative genes involved in neural specification in *C. teleta*. This will ultimately provide insight into how neural specification evolved within Bilateria.

S5-8 CARRYON, GC*; KAHN, JC; TANGORRA, JL; Drexel University; *gcarryon@gmail.com*

Sensory Mediated Control and Touch in Biorobotic Fins

Our studies of fish swimming have revealed that fish use their fins as propulsors and as sensors to swim and to navigate by touching obstacle surfaces and actively contacting the environment. This functionality implies that the mechanics and the sensory and control systems of fins are not designed solely for propulsion, but are more complex systems that evolved to satisfy a richer range of objectives. Based on neuromechanical and behavioral studies of the sunfish, we have developed biorobotic models of the pectoral and median fins that produce the propulsive forces and gaits for steady swimming, hovers, and turns, and which are instrumented with distributed sensors to measure fin ray bending and membrane pressures. These models have been used to investigate sensory-mediated control of fins during swimming and touch and to learn how to exploit biological principles for high performance robotic systems. In this talk, we will present our understanding of closed loop control applied across the continuum from steady swimming, to maneuver, to unsteady touch and propose a sensing and control framework for implementation in robotic fins.

98-4 CARTER, A.M*; HSIEH, S.T; DODSON, P; SALLAN, L; University of Pennsylvania, Temple University; *caja@sas.upenn.edu*

Vertebral ecomorphology and transitions to land in a diverse clade of early tetrapods

Vertebral size, shape, and total vertebral numbers have been correlated with ecology, feeding mechanics, and locomotor type in modern vertebrates. However, it is unclear if these morphologies are related habitat preferences in early tetrapods, critical for documenting transitions such as invasion of land. Temnospondyls were an ancient lineage of stem-amphibians that ranged in size from 5 millimeters to 5 meters, and prevailed for over 200 million years. This clade offers an excellent opportunity to examine environmental correlations on a macroevolutionary timescale because they underwent repeated diversifications into new habitats. In addition, their vertebral morphologies include over half of the categories present during the Paleozoic. Early works on this group categorized their complex vertebral diversity; however, no study has determined how this diversity affects biomechanically-relevant traits and correlates with ecology. We conducted a 2D geometric morphometric study on presacral vertebrae in temnospondyls using a total of 13 landmarks to capture neural spine and intercentrum form. We reconstructed habitat shifts using a threshold model, and tested for correlations between morphology and environment. Procrustes ANOVAs revealed a significant amount of variation in intercentrum shape is explained by habitats. Conversely, 90% of variation in neural spine size and shape is unexplained by phylogeny or habitat. Ancestral state reconstructions revealed temnospondyls were not tightly constrained and could transition into new environments every 30 million years. Vertebral innovations appear to have been critical for tetrapod habitat invasion and reinvasion, emphasizing the need for future studies on extinct tetrapods to establish patterns for vertebral form-function.

P1-278 CARTER, AW*; MOUNTCASTLE, AM; Bates College; *acarter3@bates.edu*

Mapping resilin distribution in the wings of bees and wasps

Resilin, a rubber-like protein, appears in the wings of many insects, often in flexible joints where fold-lines or flexion-lines cross wing veins. Recent work has begun to reveal the important functional roles of particular resilin joints and associated flexion-lines. For example, the 1m-cu joint in bumblebees has been found to increase aerodynamic force production and improve flight stability by promoting favorable wing flexion during flight, and the "costal break" in yellowjacket wasps has been found to mitigate collision-induced wing damage by allowing the wing tip to collapse reversibly. Beyond bumblebees and yellowjackets, however, little is known about the distribution of resilin in the wings of other bees and wasps, and the extent to which it varies across the hymenopteran phylogeny. We used confocal microscopy to map the distribution of auto-fluorescent resilin structures in the wings of over 50 hymenopteran species from more than 17 families. We found that the overall number, positions, and shapes of resilin structures varied widely across hymenopteran families, and that representatives of *Apis* (honeybees) and *Bombus* (bumblebees) were missing a costal break entirely. Our results raise important questions surrounding the functional implications of diverse wing morphologies, and the evolutionary factors and constraints that have given rise to different patterns of wing flexibility.

100-7 CARTER, W*; WHITEMAN, J; COOPER-MULLIN, C; NEWSOME, S; MCWILLIAMS, S; University of Rhode Island, University of New Mexico; *wales.carter@outlook.com*

Fatty acids in muscle differ in turnover rates and response to exercise in Zebra Finch

Muscle fatty acid (FA) composition changes in response to diet and physiological condition, which in turn affects whole-animal performance (e.g. aerobic endurance, metabolic rate, post-exercise recovery) in a wide range of taxa. The pace of compositional changes of FAs, however, remains largely unknown and limits our ability to infer their ecological consequences. We estimated the turnover rates of individual FAs in neutral lipid (NL) and polar lipid (PL) fractions extracted from the flight muscle of exercised and unexercised Zebra Finches (*Taeniopygia guttata*). FA turnover was quantified by measuring ^{13}C enrichment in tissues sampled over 256 days following a C_4 to C_3 diet shift, with the exercise treatment used to assess the effect of elevated metabolic rate on turnover. In both fractions, turnover was fastest for linoleic acid (LA, 18:2n6) and palmitic acid (PA, 16:0) with mean retention times (τ) of, respectively, 6.6 and 9.5 days in NLs and 4.1 and 5.1 days in PLs. Arachidonic acid (ARA, 20:4n6) and docosahexaenoic acid DHA, (22:6n3) were only found in PLs and had much slower turnover (τ=26.0 days and τ=41.4 days, respectively), while stearic acid (SA, 18:0) and oleic acid (OA, 18:1n9) had more intermediate turnover in both fractions. All pairs of FAs were significantly different from one another ($P < 0.05$) except for LA and PA in both fractions, PA and SA in NLs, and PA and OA in PLs. Exercise increased the turnover of LA ($\tau_{\text{exercised}} = 3.7$, $T_{56} = -2.245$, $P = 0.029$) and PA ($\tau_{\text{exercised}} = 3.8$, $T_{59} = -2.314$, $P = 0.024$) in PLs. These results demonstrate both rapid turnover of key FAs and provide evidence that multiple mechanisms drive FA turnover, including oxidative damage and the consumption of molecules during normal function.

S6-4 CASAGRANDE, S*; GARAMSZEGI, LZ; HAU, M; GOYMAN, W; HORMONEBASE CONSORTIUM, ; CASAGRANDE, Stefania; Max Planck Institute for Ornithology, Estación Biológica de Doñana-CSIC, www.hormonebase.org; *scasagrande@orn.mpg.de*

Glucocorticoid changes across life history stages: a comparative approach

Environmental fluctuations trigger changes in glucocorticoids (GCs) that promote profound individual physiological and behavioral adjustments as well as shifts in life-history stages. Baseline (BLs, low levels for predictable fluctuations) and stress-induced GC levels (SLs, high levels typical for unpredictable fluctuations) mediate metabolic and behavioral changes to obtain and utilize energy depending on needs. BLs are expected to covary with seasonal energy demands while SLs are thought to mediate life history trade-offs when unpredictable disturbances occur, like promoting survival processes at the expense of reproduction. We will employ comparative methods to analyse seasonal changes in GCs within the class Aves to identify broad-scale patterns across taxa. We will extract population GC means for breeding versus non-breeding seasons from HormoneBase, and from those calculate changes ('population scopes') in seasonal GC changes. We assume breeding is the more energetically demanding life-history stage, and therefore predict that BLs are higher during the breeding season, and a larger seasonal scope is positively related to fecundity. Conversely, we expect SLs are lower during the breeding season to minimize reproductive disruptions, and scope is negatively associated with fecundity. Controlling for phylogeny, we will construct analyses that include sex, size, metabolic rate, environmental and life history variables to understand how seasonal changes in GCs covary with life-history traits and environmental conditions of populations.

88-1 CASASA, S*; MOCZEK, AP; Indiana University, Bloomington; *ascasasa@indiana.edu*
The role of ancestral phenotypic plasticity in evolutionary diversification: population density effects in horned beetles
The role of plasticity in shaping phenotypic diversification continues to receive considerable attention. One especially debated issue concerns the significance of genetic accommodation in diversification, and the proposed role of ancestrally plastic responses in facilitating or biasing subsequent genetically canalized differentiation among taxa. Here, we investigated the role of ancestral plasticity in facilitating rapid divergence between exotic populations of the Mediterranean dung beetle *Onthophagus taurus*, introduced ~50 years ago to Western Australia and the Eastern United States. Historically, Western Australian and Eastern US populations have been subject to disparate levels of mate- and resource competition, proposed to have driven rapid heritable divergences in diverse morphological, physiological, and behavioral traits. In this study, we utilized a Spanish population as a proxy for the ancestral Mediterranean population to assess whether preexisting plasticity in response to variation in population density may have mediated these previously documented canalized divergences among descendant exotic populations. We focused on two maternal behavioral, two life history, and two morphological traits. We find that (1) Mediterranean *O. taurus* exhibit plasticity in response to adult densities for four of the six focal traits; (2) that in two of those, plastic responses match the direction of canalized divergences among natural populations; and (3) that the presence and direction of plasticity appear unrelated to trait type. Our results provide partial support for the hypothesis that evolution by genetic accommodation could have contributed to the very early stages of population differentiation in a subset of traits in *O. taurus*.

P3-153 CASASA, S*; ZATTARA, E; MOCZEK, AP; Indiana University, Bloomington; *ascasasa@indiana.edu*
Transcriptomic underpinnings of developmental plasticity and their evolution: insights from Onthophagus horned beetles
Phenotypic plasticity is a ubiquitous property of development, which itself has undergone a tremendous degree of evolutionary diversification. Even though most traits exhibit some degree of plasticity, and the developmental-genetic mechanisms underlying a subset of plastic traits are starting to be elucidated, *how* these mechanisms originated and diversified remains largely unclear. We used a comparative RNAseq approach on three species of *Onthophagus* beetles with varying degrees of nutrition sensitivity of horn growth to better understand the transcriptional basis and evolution of this plastic response. We compared one basal species, which exhibits a modest degree of nutrition responsiveness (*O. gazella*), with two derived species, one exhibiting extreme sensitivity (*O. taurus*) while the other has secondarily lost it (*O. sagittarius*). Using this approach, we seek to: 1) identify the gene repertoire whose expression is affected by nutritional variation within each species; 2) assess the extent to which nutrition-based plasticity in gene expression mirrors morphological plasticity within and across species; and 3) gain insight into the relative importance of genetic accommodation in gene expression plasticity and in the evolutionary diversification of nutrition-responsive development. More generally, we hope to better understand how patterns of gene expression underlying nutrition-responsive growth evolve in relation to the degree of morphological plasticity observed across closely related species. Given the growing attention on the role of genetic accommodation in diversification, understanding how gene expression underlying plastic traits itself evolves will be critical to better understand the mechanisms of genetic accommodation.

135-1 CASS, J.A.*; DANIEL, T.L.; Univ. of Washington; *danielt@uw.edu*
Flow and diffusion together mediate substrate delivery into the crowded lattice of contractile filaments
Muscle contraction is mediated by myosin motors that derive their energy from ATP hydrolysis. Recent research suggests that diffusion may be limiting in the exceedingly crowded lattice of thick and thin filaments. Additionally, conservation of mass implies that, for constant lattice spacing, axial and radial fluid motion must necessarily accompany periodic lengthening and shortening of the sarcomere. We asked if such flow augments the rate of ATP supply inside the sarcomere. To address this question we developed a continuum model for the diffusion-convection equation in the sarcomere, with a time-dependent flow field driven by sinusoidal sarcomere contractions. By comparing the concentration gradient of ATP along the sarcomere radius with and without convection, we find that radial flows improve ATP replenishment in the sarcomere center over diffusion alone. After the first, second, and third contraction cycles, convection improves ATP concentrations by up to 81.9%, 30.8% and 19.2% respectively. After many (>200) cycles, the difference approaches zero as the system reaches an equilibrium state. These results pertain to constant extra-sarcomeric concentrations. If, however, those concentrations are time-dependent, flow will always lead to increased substrate availability. Our results indicate that, in addition to driving axial forces, the flow induced by shortening sarcomeres can augment ATP delivery, potentially offsetting the costs associated with viscous shearing.

P3-103 CASTILLO, CR*; BALTZLEY, MJ; Western Oregon University, Western Oregon Univerisity; *ccastillo14@mail.wou.edu*
Variation in GABA-Immunoreactive Neurons Across Three Stylommatomorpha Gastropods
There is typically little variation in the structure of nervous systems of closely related species, but often variation is found in the size, number and location of individual neurons. To explore the variation of nervous systems among several gastropod species, GABA-immunoreactive (GABA-IR) cells were identified in the grey field slug *Deroceras reticulatum*. GABA-IR cells were chosen in order to compare results to previously unpublished data from the garden snail *Cornu aspersum* and the scarlett-backed taildropper slug *Prophysaon vanattae*. The three gastropods belong to the Stylommatomorpha clade and are found in the Pacific Northwest. We expected to find same number of GABA-IR neuron clusters across species, but expected to find variation in the number of cells within those clusters across the three species. In all three species, GABA-IR clusters were found in both the cerebral ganglia and in the fused pedal, plural, visceral and parietal ganglia. We found no significant difference in the number of clusters in the cerebral ganglia ($p = 0.71$; $\alpha = 0.05$; t-test) nor the pedal ganglia ($p = 0.50$; $\alpha = 0.05$) between *D. reticulatum* and *P. vanattae*. However, there was a significant difference between the number of cells per cluster across *D. reticualtum* and *P. vanattae*. The number of cells per cerebral cluster in *D. reticulatum* (8.4 ± 0.7) was less than *P. vanattae* (12.7 ± 1.0; $p < 0.0001$). Similar results were found for the number of cells per pedal ganglia ($p < 0.0001$).

P2-231 CASTILLO, ER*; LIEBERMAN, DE; Hunter College, CUNY, Harvard University; *eric.castillo@hunter.cuny.edu*

Lordosis variability and shock transmission in the human lumbar spine

Human lumbar lordosis (LL) is an adaptation for bipedalism that helps position the center of mass of the upper body over the lower limb, reducing the mechanical and metabolic costs associated with upright posture. However, fossil evidence indicates there has been considerable LL variability among hominin groups, perhaps suggesting that postural variations serve other functions. This study investigates the effects of LL on impact-related shock attenuation (SA) in the human lumbar spine during walking and running. During bipedal locomotion, each step generates a shock wave that propagates up through body toward the head, and repeated shocks can lead to pathology without active or passive mechanisms for attenuation. To test the hypothesis that LL increases SA, 27 participants (14 male, 13 female) walked and ran on a treadmill with two lightweight, tri-axial accelerometers affixed to the skin overlying T12/L1 and L5/S1. Sagittal plane accelerations were analyzed across frequencies using power spectral density analysis, and SA was measured in the impact frequency range. 3-D kinematics quantified natural standing and dynamic LL, and the effects of intervertebral discs on SA were tested using MRI scans. Results showed no correlation between LL and SA during walking, but LL correlated with SA during running ($p<0.01$, $R^2=0.30$). Multiple regression models showed that higher amplitudes of dynamic LL displacement and slower rates of displacement during running were associated with higher levels of SA ($p=0.008$, multiple $R^2=0.41$). Thicker discs were also associated with higher SA ($p=0.02$, $R^2=0.22$), but LL was a stronger predictor of SA than disc thickness when controlling for both variables ($p=0.001$, multiple $R^2=0.44$). Results support the hypothesis that a more curved lordosis reduces impact-related shock accelerations transmitted through the human lumbar spine during dynamic activities such as running.

P1-240 CASTRO, MA*; ELKHOURY, LD; FOKIDIS, HB; Rollins College, Winter Park; *macastro@rollins.edu*

The role of neuropeptide Y in the regulation of the stress response and food intake in the brown anole (Anolis sagrei).

Neuropeptide Y (NPY) is a conserved hypothalamic regulator of food intake in vertebrates, where it promotes the hunger response to encourage foraging. In addition, NPY has a complex interaction with components of the stress response both within the brain and on peripheral tissues. During a stress response, a hormonal cascade initiating in the hypothalamus, and acting through the anterior pituitary gland, eventually results in the release of glucocorticoid steroid hormones, such as corticosterone (CORT) into general circulation. Recent studies suggest that NPY can interact directly with the adrenal gland to facilitate CORT secretion. This interaction has been explored in mammals, where NPY receptors have been found on adrenal tissue, yet the general role of NPY in reptiles remains understudied. This raises the question of whether NPY can stimulate a stress response and whether a functioning stress response is required for NPY to exert its effects on food intake. Using the invasive brown anole (*Anolis sagrei*) we tested the hypothesis that NPY promotes both food intake and also CORT release. First, to test whether NPY can activate the stress response, we injected male anole lizards with either: 1) saline; 2) NPY; 3) dexamethasone, a glucocorticoid agonist which suppresses CORT release; or 4) both NPY and DEX. One hour after injection a blood sample was collected to measure plasma CORT concentrations. Second, we tested how the above treatments influenced food intake in captive anoles, by measuring the number of mealworms consumed post-injection. Injection with DEX did not increase food intake above control animals, suggesting CORT release does not itself alter feeding. Current studies are continuing to elucidate the dynamic and complex relationship between NPY, food intake, and stress.

54-2 CAVAGNARO, JW; Villanova University; *geicothetoad@aol.com*

Color Evolution and UV Reflectance in Diurnal Geckos: Influence of Visual System and Background

Perception of ultraviolet (UV) light, mediated by the SWS1 opsin, is widespread in reptiles. Many species reflect UV light as part of their coloration, but its role is understudied, because humans cannot perceive it. The UV reflectance of geckos in particular has not been investigated. The nocturnal ancestry of geckos has left them with a unique trichromatic visual system, with opsins sensitive to UV, blue, and green light, but not red. I have used objective multispectral photography and cone-catch modeling to determine how different signals stimulate the gecko visual system, so that their coloration can be interpreted in a biologically relevant context. I specifically focus on the sexually dimorphic coloration displayed by members of the diurnal genus *Lygodactylus* Gray, 1864. Several species in the genus exhibit a yellow head with a blue-grey (and UV) body, a pattern which has evolved convergently in other, independently diurnal clades. This indicates that the yellow-headed phenotype is an efficient signal for the gecko visual system in a diurnal light environment. I find that to the gecko visual system, the UV-blue-grey body and the yellow head are each most conspicuous against different natural backgrounds, providing a good signal in complex lighting and background conditions. The chromatic contrast between the head and body is higher than either against any background; this contrast may be an important component of the signal regardless of visual context. As geckos lack a red sensitive cone type, the yellow head cannot be distinguished from the green color of foliage, and for this reason has been lost in the canopy dwelling species. This species, the critically endangered *L. williamsi*, has evolved bright blue coloration with a strong UV component, highlighting the importance of UV reflectance for signaling in this clade.

15-3 CAVES, EM*; GREEN, PA; JOHNSEN, S; Duke University; *eleanor.caves@gmail.com*

Signaling in the Cleaner Shrimp-Client Fish Mutualism: Combining Behavior, Network Analysis, and Sensory Physiology

Researchers often refer to acts or structures as signals without first testing for a signaling function. To be a signal, an act or structure should at the very least (1) be perceptible by the receiver, and (2) result in a behavioral change in the receiver. Thus, before studying signal form or function, the act or structure in question must be shown to be a signal. In mutualisms, signaling between partners can impact the interaction's success, which makes them a good system for exploring potential signaling behaviors. We examined interactions between cleaner shrimp (*Ancylomenes* and *Lysmata* spp) and their client fish to determine if cleaning interactions are mediated by visual signals. Cleaner shrimp remove ectoparasites from their reef fish clients, and although up to half of client visits are by fish that eat crustaceans, cleaner shrimp are rarely eaten during cleaning interactions. One hypothesis is that cleaners and clients use visual signals to identify themselves as beneficial partners. Cleaner shrimp display complex color patterns and exhibit stereotyped behaviors in the presence of clients. Clients, in turn, adopt stereotyped poses and often change color at cleaning stations. To address the two criteria outlined above, we (1) incorporated measures of cleaner and client spectral sensitivity and spatial acuity to examine how they may appear to their mutualistic partners, and exposed cleaners to black-or-white geometric stimuli on a screen to test how they respond to purely visual stimuli. We then (2) recorded and annotated 152 hours of video of cleaner-client interactions in the Caribbean and Red Seas to identify candidate signaling behaviors. To those annotations, we applied network analysis to show which candidate behaviors altered receiver behavior.

134-5 CAVIEDES-SOLIS, IW*; LEACHE, AD; University of Washington, University of Washington ; *itzuecs@uw.edu*
Evolution of Swimming in Tree Frogs
Neotropical tree frogs of the subfamily Hylinae have three main locomotion modes with a direct impact on species fitness; they jump, swim and climb. Convergences in morphotype and locomotion are primarily driven by microhabitat, but in some cases morphology is the result of long-term phylogenetic constraints. Swimming is a critical behavior during life history for predator avoidance, reproduction, and early developmental stages. However, is still poorly understood how swimming evolved in closely related species with multiple locomotion modes. This study aims to understand the evolution of morphological traits and their influence on swimming behavior and performance in the Subfamily Hylinae. We included 225 individuals from 16 localities in Mexico, corresponding to 31 species and 14 genera. Our data set includes linear velocity of one complete swimming trial, backstroke kick (both legs simultaneously or alternating), forearm rowing present or absent, and microhabitat as arboreal (bellow or above 2m) and aquatic (still or moving water). We estimated the correlations among the evolution of traits along the phylogeny by using the threshold model. We found that Hylinae species use the two types of swimming reported for frogs, alternating gait (the presumed primitive condition in frogs) and simultaneously gait (the derived locomotion mode). In addition there is a high rate of inter- and intra- specific variation in swimming behavior and performance. Our evolutionary correlation analyses support that: faster swimming behavior is correlated with smaller limbs; a simultaneously gait is correlated with larger limb structure; microhabitat is not correlated with swimming speed or behavior; and arboreality is correlated with smaller radio-ulna and tibia. Which has important implications for the study of tree frog evolution and habitat selection.

17-5 CEASE, AJ*; WATERS, C; Arizona State University, Department of Primary Industries, NSW, Australia; *acease@asu.edu*
High protein plants may limit persistence of Australian Plague Locusts (Chortoicetes terminifera) to the outback
Locusts are grasshoppers that can form massive migrating swarms and devastate food security. Locust species tend to be concentrated in arid ecosystems but will invade croplands during upsurges. For example, Australian Plague Locust (*Chortoicetes terminifera*) outbreaks mainly originate in the outback and invade agricultural areas closer to the coast. However, locusts often do not persist in these invasion zones. We tested the hypothesis that high soil fertility constrains locust populations by creating a nutritionally poor landscape of high protein plants. In contrast to the commonly-held hypothesis that herbivores are ubiquitously nitrogen and protein-limited, we found that, similar to the Mongolian Locust, field populations of the Australian Plague Locust grew and survived best on low-nitrogen (low protein) plants and artificial diets with a 1:2 mass ratio of protein: carbohydrate. When we confined locusts to N-rich grasses in their invasion zone, they self-selected an almost entirely carbohydrate diet for about 3 days. We paired field-station based experiments with field surveys spanning NSW from the agricultural belt to the outback. Locusts were most abundant where grasses had a low protein: carbohydrate content. These results support our hypothesis that high soil fertility in croplands limits persistence of Australian Plague Locusts in these areas by increasing plant protein content.

P3-243 CEJA, AY*; GUNDERSON, AR; STILLMAN, JH; Univ. of California, Riverside, Univ. of California, Berkeley, Univ. of California, Berkeley; San Francisco State Univ.; *aceja005@ucr.edu*
What makes a crab move, and where does it go? Modeling predicts shifts of an intertidal population distribution and abundance in response to warming
Climate induced shifts in population distributions have been well documented globally across marine and terrestrial ecosystems. In contrast, few studies have focused on local distribution shifts in small scale variable environments. The rocky intertidal shore is known for exhibiting a highly thermally variable environment ranging up to 40°C within an elevational gradient of a few hundred meters and temporal range of hours. This extreme thermal variability has led to the exploitation of intertidal shores in global warming research. An individual-based simulation was created to test a here newly developed rule-based size-dependent species distribution model of a well understood intertidal population of *Petrolisthes cinctipes* crabs found at Fort Ross State Historic Park, California. The model implemented the use of real environmental, behavioral, and physiological data collected from Ft. Ross. A future environmental thermal profile, generated here, was employed in the simulation to predict the distribution of the population in response to warming. Results predict the population will respond to warming by shifting their distribution lower in the intertidal zone as well as decreasing population abundance. Local population abundance and distribution shifts affect individual relationships across all levels from predators and prey to competitors and symbionts. These changes in relationships could result in significant repercussions to community dynamics, potentially fostering ecosystem-wide community alterations. The generated model and simulation, created in the modeling software NetLogo, could be applied to similar systems of less tractable organisms responding to biotic and abiotic variables across local or global elevational gradients.

P3-19 CERIO, DG*; WITMER, LM; Ohio Univ.; *dc441511@ohio.edu*
Visual Fields of Dinosaurs and their Extant Relatives: Bony Evidence and Soft-Tissue Reconstruction
The visual abilities of dinosaurs as they relate to ecology and behavior have been the subject of recent interest. Orbital soft tissues have received little attention, and, if ignored, the eyeballs of dinosaurs may be missized or positioned inaccurately, leading to poor estimates of visual fields and spurious conclusions about behavior and ecology. Fossils of extinct dinosaurs were studied firsthand to identify the osteological correlates (OCs) for orbital soft tissues including the extraocular muscles, cranial nerves, glands, eyelids, supraorbital membrane, subocular ligament, and nasolacrimal duct. Intact heads of 27 species of birds, crocodylians, and squamates were subjected to iodine-enhanced microCT (diceCT and spiceCT), and several dozen additional avian specimens were microCT-scanned without iodine contrast. Orbits were dissected to validate the CT studies and to identify the OCs for orbital soft tissues. Soft tissues and endosseous labyrinths were segmented in Avizo, and soft tissues were modeled in Maya. Estimates of eyeball size and optical parameters including focal length and monocular visual field, which depend in part on eyeball size, shape, and position, were modeled. Visual fields based on these optical parameters and constraints were modeled and tested against empirical measurement of visual fields in the literature. The results indicate that reconstructing accessory soft tissues in the orbits of extant diapsids can provide upper limits on estimates of eyeball diameter, axial length, and the geometry of visual fields, whereas lower limits are currently less constrained (although under study). Based on the findings from the CT and fossil studies, eyes, accessory soft tissues, and visual field geometry were modeled for several extinct archosaurs, including moa and early ornithischian dinosaurs.

49-3 CERKVENIK, U*; VAN DE STRAAT, B; GUSSEKLOO, SWS; VAN LEEUWEN, JL; Wageningen University, The Netherlands; *uros.cerkvenik@wur.nl*

How parasitic wasps steer ovipositors and avoid buckling during probing

Drilling in solid substrates with slender probes is challenging, but is normal behavior of many parasitic wasps. Females use their thin ovipositors to search for and deposit their eggs in/next to hosts hidden within the substrates. The ovipositor consists of three valves that are longitudinally connected with a rail-like structure, enabling them to slide along each other. Alternating valve movements have been hypothesized to play a role in damage avoidance and steering during probing. We tested these hypotheses *in vivo* by quantifying the probing kinematics of the parasitoid *Diachasmimorpha longicaudata* (Braconidae) in transparent gels of two different stiffnesses. The quantification of valve motion revealed their different functional roles and effects on the shape of the ovipositor tip. We further investigated the valves' mechanical properties by measuring their bending resistance. We show that wasps were able to probe in any direction relative to their body. Steering of the ovipositor is achieved by changing the shape of its tip, which is done by adjusting the valve offset. Upon the protraction of the ventral valves, the asymmetry was enhanced due to curving of these valves toward the dorsal one which increased the asymmetry of the tip forces. Furthermore, alternating valves were always used when drilling in stiff gels, whereas ovipositors can be inserted without such movements in soft gels. This indicates that reciprocal movements are needed in high-friction environments, presumably for buckling avoidance. Similar probing kinematics was observed in mosquitoes and suggested to occur in hemipterans. The increased knowledge on the functional morphology of multi-element insect probes may stimulate the development of new bioinspired minimally invasive tools.

119-3 CESPEDES, AM*; LAILVAUX, SP; Univ. of New Orleans; *anniecespedes@gmail.com*

Conflict and the evolution of sexual dimorphism in whole-organism performance

Intralocus sexual conflict arises when males and females experience divergent selection pressures and, due to their shared genome, the response to selection pushes one sex away from their respective fitness optimum. One way to resolve or reduce sexual conflict is to allow each sex to approach separate optimal phenotypes, resulting in sexual dimorphism. Whole-organism performance traits are integrated morphological and physiological phenotypes and are often subject to sex-specific selection. Selection for male performance in combat, for example, affects the evolutionary trajectories of both sexes. As performance traits rely on the additive effects of many genes necessary for development and survival, sexual dimorphism in performance may be constrained due to correlated expression between males and females. Furthermore, performance traits are typically subject both to competing selection pressures and to trade-offs with other types of performance that rely on conflicting physiological and skeletomuscular phenotypes. Finally, animals do not always perform at their maximum capacity, which can alter the effects of selection. Yet sexual conflict in performance is not given much attention. In this study, we created an individual-based simulation to test how multiple performance traits evolve in response to sex-specific selection pressures under various constraints. By manipulating energy budgets and performance costs; functional and genetic trade-offs among traits; and intersexual genetic performance correlations, we show how balancing performance demands, energy requirements, and sex-specific selective paradigms alters the direction, shape, and intensity of selection, and ultimately drives separate trajectories of performance evolution in males and females.

P1-19 CHABAIN, J*; KOLMANN, M/A; SUMMERS, A/P; CHABAIN, Jules; FHL, Univ. of Montpellier, France, FHL, Univ. of Washington, Wash.; *jules.chabain@hotmail.fr*

What's the Point? Form and Function of the Caudal Barb in Stingrays

Animal weaponry are diverse and serve a variety of roles; from the asymmetrically-sized and largely-ceremonial chela of fiddler crabs, to the venomous spurs of male platypuses, these structures can defend against predators, intimidate rivals, or attract mates. Stingrays (Myliobatiformes) are the most ecologically-diverse lineage within the modern elasmobranchs (sharks and rays) and have an enlarged, venomous caudal barb formed from hypertrophied dermal denticles, which these rays use to defend themselves from predators. Barbs display diverse morphologies. We used micro-computed tomography to examine barbs from over 40 species, representing the major families in Myliobatiformes; including Potamotrygonidae (*Potamotrygon*, *Plesiotrygon*), Dasyatidae (Dasyatinae, Neotrygonidae), Myliobatidae (*Rhinoptera*), Urotrygonidae (*Urotrygon*, *Urobatis*), Urolophidae, and Gymnuridae . As expected barb shape was distinctive with each species, with previously undescribed variation in morphometry and meristics. For example, the spine of *Paratrygon aiereba* is distinguished by large rounded base, with large bilaterally symmetrical central serrations, and an overall teardrop shape. In contrast, the spine of *Plesiotrygon iwamae* is largely covered by small disorderly serrations, along a uniform beam-like shape. In cross section, barb morphology is also variable and can be oval, triangular, or more complex. We used a phylogenetic framework to assess the variability of barb shape stems from inheritance or if there is an ecological signal as well. We generate functional hypotheses to explain barb morphological diversity using analogies with edged weapons, different sword and arrow shapes, which are specialized for either slashing or puncture.

P2-36 CHABRIA, T*; MASSENA, K; FUNK, A; DANISEWICZ, E; THOM, Z; MASS, S; State University of New York at New Paltz; *chabriat1@hawkmail.newpaltz.edu*

Interaction of BHT with BPS in Planaria

Bisphenol compounds such as BPS are environmental endocrine disruptors that act as xenoestrogens. BPS is commonly used to make certain types of plastics and epoxy resins that are used in food packaging, thermal printing and a variety of other consumer and industrial products, and is commonly substituted for BPA in "BPA-free" products. Prior work in our lab has demonstrated that moderate to high doses of BPS adversely affect regeneration in flatworms. Common antioxidants like Butylated-hydroxytoluene (BHT) that are used as preservatives in foods and cosmetics have been coming under renewed scrutiny as potential endocrine disruptors and carcinogens. In this work, we examine the effects of co-administration of BHT with BPS at doses below the LC50 for BPS.

53-4 CHABY, LE*; LIBERZON, I; CHABY, Lauren; University of Michigan; *lauren.chaby@gmail.com*

Thanks for being flexible: Cognitive flexibility training can attenuate the effects of a rodent trauma model on fear learning and memory

Exposure to stress can cause lasting changes in cognition, but some individual traits, such as high cognitive performance, can reduce the degree, duration, or severity of cognitive changes following stress. Here, we test whether cognitive training or high cognitive performance can attenuate changes in fear memory using a rodent trauma-model called single prolonged stress. Exposure to single prolonged stress typically heightens fear responses even after a fear association has been extinguished (by reducing extinction retention), which may reflect changes in context processing. We used cognitive flexibility training to assess individual variability in cognitive skills and to condition rats to discriminately use information in their environment. We found that cognitive flexibility training enhanced both fear extinction learning and extinction retention, compared with rats that did not undergo cognitive training. Further, when cognitive flexibility training was followed by exposure to a trauma-model, we found accelerated extinction learning and an increased rate of extinction retention in the second half of testing, compared with rats that were not trained but were exposed to the trauma-model, suggesting that cognitive flexibility training may attenuate context processing changes. At the individual level, cognitive performance during only one phase of the cognitive flexibility training predicted subsequent fear responses; rats that were high performers in the reversal learning phase of the cognitive flexibility training had an increased rate of extinction retention compared with low reversal performers, suggesting that this aspect of cognitive performance may be most important in predicting changes in context processing following stress.

P2-171 CHADDA, A*; PRATT, B; DANIEL, T; HSING, I; Hong Kong Univ. Sci. Tech., Hong Kong, Univ. Washington, Seatte; *danielt@u.washington.edu*

Abdominal mechanosensors encode body flexion in the hawkmoth Manduca sexta

Animal flight stability can be attributed to the rapid control mediated by mechanosensory feedback. In insects, this control involves reflexive changes in airframe configuration for redirection of lift forces. There is ample proof that visual stimuli drive this active control of the abdomen including morphological evidence that sensory hair plates are distributed in critical regions around abdominal joints. However, the neural encoding of this crucial sensory system remains poorly understood. To explore encoding properties of abdominal mechanosensors in the hawkmoth *Manduca sexta*, we delivered white noise mechanical stimuli to the abdomen-thorax joint and recorded extracellular neural responses from the ventral nerve cord. We used spike-sorting analyses to identify the single neural units and further extracted the stimulus features that most likely generate action potentials. We identified the spike triggered average (STA) which represents the average motion stimulus that generates spikes. We found that the abdomen-thorax joint indeed contains units which respond rapidly (5 - 10 ms) and preferentially to a certain feature in the stimulus. We were also able to determine the specificity to the STA by calculating the probability of spike generation given the STA and found that units fire not only with high temporal precision, but also high fidelity to a stimulus feature. Taken together these results show that there is neural evidence for mechanosensory information from the abdomen to modulate insect flight dynamics. These results demonstrate the presence of ubiquitous encoding properties across many taxa and mechanosensory structures, including halteres, wings, antennae as well as the abdomen

MOORE-1 CHAMANY, Katayoun; Eugene Lang College for Liberal Arts, The New School; *chamanyk@newschool.edu*

From STEM to STREAMD: Responsibility, Arts, and Design for Inclusive Learning

Confronting challenges like climate change, population growth, communicable disease, and the gathering, analysis, and management of large data sets, requires an interdisciplinary and collaborative approach. The shift to include the Arts and Humanities in STEM education (STEAM) is a first step. However, to promote the development of socially responsible scientists and scientifically literate individuals capable of shaping socially just policy informed by evidence and data, we must do more. Though Bruno Latour launched a post-modern attack on science as authority via the "Science Wars" during the 1980s, he is now championing "science as a way of knowing" and investigating how a Lovelockian approach to planetary health can combat the current flight from reason. Alongside this shift, is the DIY Science/Maker movement that: takes science out of the ivory tower and places it in the hands of communities; catalyzes interest in lab-based citizen science; and utilizes on-campus, off-campus, and on-the-web resources. To tap this growing interest, we can incorporate visual narratives to communicate the interdisciplinary, temporal, and spatial aspects of basic and applied scientific research to those outside the field. Collectively, these approaches emphasize "Responsibility" in STEAM education, capturing a wider audience through lab-based learning, "Design" principles, and infographic thinking (STREAMD). In this presentation, I will share some initiatives that support community collaboration and authentic story-telling, and describe some of the challenges associated with implementation. More specifically, I will highlight projects that use a social justice and interdisciplinary framework to offer multiple portals for engagement by those typically underrepresented in science.

P1-179 CHAN, JK*; THORNTON, JA; RIFFELL, JA; University of Washington; *jkchan@uw.edu*

Change is in the Air: Atmospheric Chemistry Impact on Floral Scent and Plant-Pollinator Interactions

Floral scent is important to pollinators for locating flowers as it relays information to pollinators regarding the quality of floral food resources. Pollinators need to track floral scent in a dynamic chemical environment, and these scent signals are vulnerable to interference by degradation and conflicting odor signals in the atmosphere. In this study, we aim are determining how atmospheric chemical reactions affect floral scents, and how that alteration impacts pollinator olfactory responses and behaviors. We hypothesize that chemical components of the atmosphere negatively affect the efficacy of pollinator behaviors by degrading or masking floral scent signals. The *Oenothera pallida - Hyles lineata* plant-pollinator system is an excellent model to examine these effects. Analysis of the *O. pallida* scent showed a number of volatiles that are attractive to *H. lineata*, including volatiles methyl salicylate. Using a High-Resolution Time-of-Flight mass spectrometer to analyze the decomposition of methyl salicylate (in the presence of hydroxy radicals and ozone in a flow tube, demonstrating that the free radicals rapidly degraded the floral volatiles. In parallel, neurophysiological recordings from the moth's antenna showed strong changes in responses to these degraded floral scents.. Results thus far have suggested that atmospheric chemical decomposition of *O. pallida* floral scent components may have strong effects on the detection of floral scent signals by *H. lineata*, which may negatively affect the pollination success of *O. pallida* in the field.

127-3 CHAN, AN*; GONZALEZ-GUERRERO, LA; IGLESIAS-PRIETO, R; BURMESTER, EM; ROTJAN, RD; BAUMS, IB; Penn State, Billion Oyster Project, New York, Boston Univ.; *anc164@psu.edu*

A Facultatively Symbiotic Coral is More Thermotolerant than Its Algal Symbiont

While tropical corals exist within a narrow temperature range, the scleractinian coral *Astrangia poculata* extends over 11 degrees of latitude. Colonies of *A. poculata* are facultatively symbiotic, which provides a unique system for studying the coral host with and without the algal symbiont. Eight colonies of *A. poculata* were collected from Naragansett Bay, RI, and fragmented into four pieces. Genetically identical symbiotic and aposymbiotic fragments were exposed to increased temperatures for three weeks. Maximum photochemical efficiency (Fv/Fm), respiration, photosynthesis, and reflectance were measured throughout the ramping period from 18 to 30°C, and during the hold at 30°C. RNAseq analyses are underway. No death was observed, thus *A. poculata* colonies from the northern range edge are able to acclimatize to temperatures consistent with the southern edge. However, the extreme high temperatures did damage photosystem II reaction centers in the algae, as evidenced by decreased photochemistry and maximum photosynthetic rates. Metabolic responses to extreme temperatures were genotype specific, with some host and symbiont combinations maintaining a steady respiration rate and others elevating their rates. Previous studies of coral metabolism genes under high temperature exhibited variable expression patterns, perhaps due to the influence of the algal partner. Instead, our comparison of differentially expressed genes between aposymbiotic and symbiotic fragments will differentiate the metabolic response of the coral host to thermal stress from the host response to a stressed algal partner. These results show that the thermal tolerance of the coral is higher than the symbiont, and that considering both is important when predicting the effects of climate change.

P3-135 CHANDRASEGARAN, K.*; SINGH, A.; LAHA, M.; QUADER, S.; SINGH, Avehi; National Centre for Biological Sciences, Reed College, National Centre for Biological Sciences, Nature Conservation Foundation, National Centre for Biological Sciences; *avehi.singh@gmail.com*

Playing it safe? Behavioral responses of mosquito larvae encountering a fish predator

Detecting and responding to predators is crucial to the survival of prey populations. We used mosquito larvae (Aedes aegypti) to study behavioral responses to predation by guppies (Poecilia reticulata). We tested the relative importance of chemical cues, both in isolation and in combination with physical cues, in eliciting anti-predator behaviors. Larvae responded more strongly, by reducing the duration of their wriggle bursts, when presented with a combination of chemical and physical cues than chemical cues alone. We also found that, under predation risk, starved larvae were willing to take more risks than satiated larvae, indicating a cost to anti-predatory behaviors. Finally, we tested whether anti-predator behaviors increase prey survival. To do this, fish were made to choose between displays of simulated larvae moving in short and long wriggle bursts. The fish preferentially attacked larvae moving in long bursts, demonstrating the survival value of the larval anti-predatory response of shifting to a preponderance of short wriggle bursts. Our study identifies specific ways in which trade-offs between predation risk and energetic costs could affect anti-predator behavior.

43-2 CHANG, S.W.*; KOEHL, M.A.R.; DUDLEY, R.; MUIJRES, F.; Univ. of California, Berkeley, Wageningen University, The Netherlands; *swchang@berkeley.edu*

Effects of carrying a blood meal on take-off performance and flight kinematics of malaria mosquitoes (Anopheles coluzzii)

Many species of flying animals carry loads when airborne. Mosquitoes can fly with a blood load equal to or higher than their unfed body mass. We studied how carrying blood loads affects the take-off performance of female malaria mosquitoes, the fitness of which depends on their ability to escape from a host after blood feeding. We used stereoscopic high-speed videography data of female *Anopheles coluzii* during takeoff to measure their 3D wing and leg motions. Comparing unfed with blood-fed mosquitoes allowed us to assess how takeoff performance was affected by a blood load, and to determine how they changed their kinematics when carrying this load. During the non-aerial phase of takeoff (prior to lift-off, when their feet leave the substratum), mosquitoes straighten their legs and beat their wings. The duration of the non-aerial phase was longer for bloodfed animals than for unfed ones, and their bodies were oriented more vertically when they carried a blood load in the abdomen. At the moment of lift-off, the velocity of bloodfed mosquitoes was 20% lower, and their ascent angle was 26% lower than those of unfed ones. Once airborne, bloodfed females flew along more horizontal paths than did unfed ones (average trajectory angle of the aerial phase was 57% lower), such that bloodfed females flew at heights that were 33% lower than those of unfed ones. Female *A. coluzii* also responded to carrying blood loads by increasing their wing stroke amplitude, but not by changing wingbeat frequency. Thus, once airborne, the flight speeds of blood-carrying animals were the same as for those without loads. These results demonstrate partial kinematic compensation for increased loads but also reduced speeds and angles of takeoff, possibly influencing escape success from the host.

8-2 CHANG, E.S.*; ORIVE, M.E.; CARTWRIGHT, P.; University of Kansas; *eschang1@gmail.com*

Genomic Insights into the Potential for Evolutionary Conflict within Hydrozoan Colonies Formed Through Fusion of Polyps

Although the vast majority of the hydrozoan clade Aplanulata comprises species that display a solitary benthic stage, some members of the genus *Ectopleura* appear to have re-evolved coloniality superficially similar to other hydrozoans outside Aplanulata. However, these colonies are not formed in the manner typical of other hydrozoans via asexual budding in the adult colony. Rather, the colonies of *Ectopleura larynx* are the products of fusion of sexually reproduced offspring onto parent colonies. As a result, individual colonies form from chimeric mixtures from genotypes, setting up a potential evolutionary conflict. If chimeric lineages vary in their ability to access the germline, germline parasitism may arise where one lineage gets most of the reproductive output while not contributing equally to the somatic functioning of the colony. In order to assess the extent to which the potential for germline parasitism is present in *E. larynx* given its novel mode of colony formation, we determined the level of genetic variation in an *E. larynx* colony relative to the accessible genetic variation in the local area and characterized genetic relationships present in colonies of *E. larynx* using a RAD-seq approach. Our results indicate that *E. larynx* colonies comprise a combination of polyps that vary in genetic relatedness from clones, to siblings, to non-siblings. However, the potential conflict inherent in this genetic chimerism is potentially mitigated by the extremely low overall genetic diversity found in populations of *E. larynx*, with minimal genetic distinction between self- and non-self in these populations.

97-6 CHANG, E.*; MATLOFF, LY; STOWERS, AK; LENTINK, D; Stanford University; *echang7@stanford.edu*

Feathered wings: how underactuated wings morph to widen the performance envelope of gliding flight

Birds change the shape of their wings through a variety of poses during gliding to precisely control their flight. To test hypotheses about mechanisms that enable robust wing morphing and to quantify their effects, we developed a bio-hybrid flying robot including 40 primary and secondary feathers. We employ an underactuated system to drive feather motion by actuating the proximal and distal feather in each wing based on measured feather and wing bone kinematics from a pigeon (*Columba livia*). Through outdoor flight tests, we validate the effectiveness of an underactuated wing with many morphing elements in real-world flow environments. Furthermore, we examine how both asymmetric and symmetric wing morphing affect flight performance and enable controlled maneuvers. We compare our flight test results against predictive performance models of our robot with morphing wings as well as with conventional aircraft control surfaces. This work expands our understanding of the role of feathered wing morphing in avian flight.

18-2 CHANG, J*; ALFARO, ME; Univ. of California, Los Angeles; *jonathan.chang@ucla.edu*

Building the complete ray-finned fish tree of life using taxonomy and birth-death models

The tree of life metaphor has been used since Darwin to depict the evolutionary relationships among all organisms. To approach this goal, recent advances in sequencing technology, as well a supermatrix and supertree approaches, have helped biologists generated large, well-sampled phylogenies. Although completely-sampled phylogenies remain rare in large clades, the comparative methods that researchers use are commonly believed to accommodate incompletely sampled phylogenies. We show that incompletely sampled phylogenies, can in some cases result in less accurate estimates of diversification rate. We then develop a new method to place unsampled species onto an existing backbone phylogeny, using taxonomic information and local estimates of diversification rate. We demonstrate this method on the largest ray-finned fish phylogeny assembled with over 11,000 tips, to create the complete fish tree of life consisting of 31,526 species. Adding unsampled lineages to our backbone phylogeny improves estimates of tip-specific speciation rates for over 60% of our sampled lineages, while also supplying a measure of uncertainty around this new estimate. Our method therefore permits a more detailed estimate of macroevolutionary rate compared to using an incompletely sampled phylogeny.

P3-43 CHAPMAN, JT*; OWENS, JD; FABELA, FF; RANDLES, S; VILLATORO, R; MAY, MA; VASQUEZ, MC; TODGHAM, AE; TOMANEK, L; Cal Poly San Luis Obispo, UC Davis; *jtchapma@calpoly.edu*

Effect of Thermal Stress and Food Availability on Particle Transport in the Gill of Mytilus californianus

Mussels (*Mytilus californianus*) are major inhabitants of intertidal zones along the California coast and serve as indicators for the effects of climate change in marine systems. We are interested in studying how environmental stressors, such as increased temperature and shifts in food availability, affect mussel physiology across multiple biological levels. Thermal tolerance in *M. californianus* may be tied to food availability, although the mechanism that underlies this link is not well understood. We acclimated mussels to different combinations of feeding regimes (1.5% and 0.25% mussel dry weight·day^{-1}) and daily maximum temperature during emersion (20 and 30°C) to look at the effects of acclimation on the ability of the mussels to respond to acute heat stress (33°C). We sampled mussels at the beginning and end of each high tide cycle for 48 h before and after heat shock. Because the gill tissue is responsible for transporting food from the environment, we used particle velocity, the rate at which particles pass along the gill, as a proxy for the mussels' response to temperature stress. Using high definition video, we tracked the movement of fluorescent beads along the surface of an excised piece of gill tissue from individuals in each treatment (n = 4). Videos will be analyzed using Particle Image Velocimetry (PIV) software to look at the effects of food availability and thermal history on the ability of mussels to recover from acute heat stress. We predict that mussels acclimated to low food availability will recover more slowly from heat shock, manifested in slower particle velocities, compared to the high food groups, resulting from depleted energy stores (funded by NSF IOS-1557500).

108-6 CHAPPELL, DR*; SPEISER, DI; Univ. of South Carolina, Columbia; *danielrc@email.sc.edu*

Does the visual system of the eyed chiton Acanthopleura granulata function as an optical tripwire?

Most research on visual systems has focused on animals with paired cephalic eyes; however, some animals have many eyes distributed across their body. These distributed visual systems are thought to be ‘burglar alarms' which help alert the animals to the presence of predators.The study of distributed visual systems has focused on eye structure and whole animal behavioral responses to infer visual system functionality, but we know little about the neural circuitry that serves as the functional link between the eyes and the behavioral responses. The chiton *Acanthopleura granulata* (Mollusca: Polyplacophora) has hundreds of eyes embedded in its shell-plates, a robust anti-predatory response to the appearance of objects, and a relatively simple nervous system, all of which makes it a promising system for learning about efficient multisensor integration and processing. We developed a conceptual model in which *A. granulata* integrates visual information locally using coincidence detection to combine noisy input from many eyes to provide accurate output to effect reflexive anti-predatory behavior. To better understand the sensory input that is processed by the nervous system of *A. granulata*, we used electroretinography to find the spectral sensitivity of the eyes as well as the critical flicker fusion rate which was found to be 35-40 Hz. Next, to validate the neural circuitry proposed by our model, we used fluorescent dyes to trace optic nerves from the eyes to their sites of innervation along the lateral nerve cord. Although *A. granulata*'s visual system presents a computational hurdle to its simple nervous system, it seems to mitigate this by processing visual information with a neural circuit design commonly used to process distributed mechanosensory information.

P3-173 CHASE, HT*; O'BRIEN, E; TOBALSKE, BW; University of Montana; *hilatzipora@gmail.com*

Birds and Bone: Trabecular Morphology in the Avian Shoulder

To understand the evolution of flight in the avian lineage, it is necessary to resolve the functional morphology of the flight stroke. Thus far, studies have focused only on the cortical bone in wings. Trabecular bone more rapidly adapts to joint loading, and can provide subtle and specific mechanical signals within bone that correlate with behavior. Though trabecular analyses have led to major discoveries in mammalian biomechanics and evolution, trabecular morphology in relation to bird flight has yet to be explored. To begin to assess structure-function relationships in the avian shoulder, we used existing kinematic and mechanical data from various species to model the loading regime for different flight styles (e.g. flapping, soaring). We collected microCT scans of the proximal humerus in a broad, comparative set of museum specimens and an ontogenetic series of chukars. Trabecular structure was related to flight style, in combination with body size and phylogeny. Both mean trabecular thickness (Tb.Th) and the degree of anisotropy (DA) in the humeral head appeared to be highest in raptors, which habitually soar or flap-glide. Comparatively, Tb.Th and DA tend to be low in ground birds, which engage only in short bursts of flapping flight. Additionally, we found that Tb.Th scales allometrically, proportional to the 0.185 power of mass, which is lower than has been reported in the femur of birds and closer to the scaling exponent found in mammals. In the ontogenetic series of chukars, it appears that an initial increase in Tb.Th was concurrent with the onset of lift production, while DA decreased with age. Elucidating the relationship between trabecular structure and flight mechanics in the avian shoulder provides significant insight into extant flight and a fundamental resource for fossil interpretation in the avian lineage.

13-3 CHATTERJEE, P*; MOHAN, U; DAVE, S; SANE, SP; National Centre for Biological Sciences, Tata Institute of Fundamental Research; *payelc@ncbs.res.in*

Visual and Antennal Mechanosensory feedback mediates gaze stabilization in flying moths

Insect flight initiation requires closely-coordinated reflexes, like antennal positioning, head motion, wing initiation and leg extension. During rapid maneuvers, insects actively move their head to reduce motion blur. In Diptera, this behavior is mediated by vision and rapid mechanosensory feedback from halteres, the modified hindwings. How do non-Dipteran insects lacking halteres stabilize gaze in rapid timescales, especially in low light when visual transduction is slow? To address this, we measured compensatory head movements in tethered Oleander hawkmoths, *Daphnis nerii* in response to variable-frequency roll stimuli in dark vs. light conditions. Normal moths could not gaze-stabilize for low-frequency roll stimuli in low light, but they could under bright light. Interestingly, at high roll frequency in dark, moths could gaze-stabilize, suggesting that non-visual cues are used for head stabilization. We tested the hypothesis that antennal mechanosensors mediate this feedback. Moths with detached flagella did not stabilize their head in low light at all roll frequencies and their performance under bright light was worse than antennae-intact moths. Flagella-reattached moths performed similarly to those with intact antennae. Thus, both vision and antennal mechanosensory feedback are required for head stabilization.

74-7 CHAUDHARY, G*; FUDGE, DS; EWOLDT, RH; University of Illinois at Urbana-Champaign, IL, Chapman University, Orange, CA ; *gchaudh2@illinois.edu*

Self-similar mechanics of hagfish slime

Hagfish make a unique material with remarkable properties. When provoked or attacked, the animal releases a small volume of biopolymer/biofilament material that unfolds, assembles,and expands in water by a factor of 10,000. The resulting gel is cohesive, forming a clogging network used for defense. The successful use of the defense gel is remarkable considering that hagfish cannot control the concentration of the resulting gel directly; they simply exude a concentrated material into an "infinite" sea of water. This raises questions about the robustness of gel formation and properties across a range of concentrations. In this work, we study the concentration dependent mechanics of hagfish defense gel. We observe that viscoelastic properties are linearly dependent on concentration over the range explored. From our observations of similar power-law creep response at all concentrations, we infer that hagfish slime has a self-similar structure regardless of its concentration. Using constitutive model fits, we propose that this self-similarity originates from a concentration-independent fractal dimension of the underlying slime structure. With simple geometric arguments, we show that the ultra-soft mechanics of slime results from the bending dominated response of the underlying fibrous microstructure. Our findings illustrate unusual properties of slime, which may be vital in the context of its physiological use, and may provide inspiration for the biomimetic design of materials.

64-7 CHAVAN, AR*; GRIFFITH, OW; MAZIARZ, J; PAVLICEV, M; TZIKA, A; MILINKOVITCH, M; FISHMAN, R; KOREN, L; WAGNER, G; Yale Univ., USA, Yale Univ, USA, Cincinnati Children's Hospital, USA, Univ. of Geneva, Switzerland, Bar Ilan Univ., Israel; *arun.chavan@yale.edu*

Evolution of embryo implantation was enabled by the origin of decidual cells in eutherian mammals

Embryo implantation is the first step in the establishment of pregnancy in eutherian (placental) mammals. Although pregnancy arose before the common ancestor of marsupials and eutherians (Theria), implantation is unique to Eutheria. The ancestral therian pregnancy likely involved a brief fetal-maternal attachment followed by birth rather than implantation, as in many marsupials. Here, we elucidate the evolutionary mechanism by which the ancestral fetal-maternal attachment was transformed into implantation. We used transcriptomics and immunohistochemistry of uteri of four eutherians - armadillo, hyrax, tenrec, and rabbit; and a marsupial outgroup, opossum. This allows inference of the eutherian ancestral state. Our results show that implantation evolved from an ancestral inflammatory response, a natural uterine reaction to the fetus when pregnancy arose in Theria. In Eutheria, this inflammation was domesticated such that the fetal-maternal attachment results in embryo implantation rather than birth. This was achieved by retaining components of the inflammatory response beneficial to placentation (angiogenesis, vascular permeability); while blocking the detrimental neutrophil infiltration through suppression of IL17A cytokine signaling. Using in vitro experiments, we show that the suppression of IL17A signaling was caused by uterine decidual cells, a novel cell-type in Eutheria. These results provide a mechanistic understanding of the early evolution of eutherian pregnancy, and also identify the ancestral function of an evolutionary novelty, the decidual cell-type.

20-3 CHAVEZ-DOZAL, A.A.*; SOTO, W.; NISHIGUCHI, M.K.; New Mexico State University, College of William and Mary; *albitac@nmsu.edu*

Understanding the evolution of wrinkly phenotypes in environmental and symbiotic Vibrio fischeri

Many types of bacteria increase population diversity by phase variation that allows survival and evolutionary success. One example of such variation is the symbiotic bacterium *Vibrio fischeri* (g-Proteobacteria: *Vibrionaceae*) that can switch from a smooth to a wrinkled or rugose phenotype characterized by the secretion of polysaccharides. These changes in colony morphologies also affect the ability of *V. fischeri* to colonize their animal hosts. Phenotypic variation between smooth and rugose colonies is tightly controlled by changes genetic expression that extend beyond the simple overall morphology. In the present study we conducted a transcriptomic expression profile by RNA sequencing of the rugose and smooth variants of multiple isolates of *V. fischeri*. Expression profiling led to identification of 130 differentially regulated genes, including overexpression of genes involved in oxidative stress, surface structures, and metabolic processes in the rugose variants. In contrast, there was an increase in expression of genes related to membrane transport in smooth variants. Transcriptome signatures also consisted of upregulated genes involved in biofilm formation, environmental sensing and persistence, and signal transduction, which were shared by both smooth and rugose variants. Bioinformatic analysis of these expression data shows that "rugosity" and "smoothness" are determined by a complex hierarchy of genetic regulators, that provide a better picture for *Vibrio* ecology, and mechanisms for successful survival in the host and environment.

P1-190 CHAVEZ-DOZAL, A.A.*; SALAS, S.S.; LAMI, R.; NISHIGUCHI, M.K.; New Mexico State University, Laboratoire Arago, Banyuls sur mer; *albitac@nmsu.edu*

Deciphering microbial communication in a beneficial mutualism: Cross species quorum sensing between Vibrio logei and Vibrio fischeri symbionts in Sepiola affinis (Mollusca: Cephalopoda)

The beneficial association between squids in the family Sepiolidae (Mollusca: Cephalopoda) and bioluminescent bacteria in the family *Vibrionaceae* form a unique relationship that provides a model to study the interactions between animals and bacteria. Sepiolid squids from the Mediterranean Sea (genus *Sepiola*) are unique in that these squids serve as hosts for two bioluminescent bacterial species: *Vibrio logei* and *Vibrio fischeri*. Quorum sensing, or cell-to-cell communication regulates luminescence genes in both bacterial species, which generate the appropriate amount of bioluminescence within the squid to match any down- welling moonlight. Interestingly, little is known about how these two species are capable of communicating between each other during symbiosis. Therefore, we examined the mechanisms of quorum sensing between *V. fischeri* and *V. logei*, two luminescent symbionts found in *Sepiola* light organs. We created a null mutation on the response regulator gene *luxO* to determine whether mutations at this locus affect the ability of bacteria to communicate within and between both species during symbiosis. Our results demonstrated that *luxO* is required for luminescence production, but additional secondary regulatory genes are responsible for *luxO* regulation after a 24-hour time period. Understanding how bacteria are able to communicate within a closed system such as the sepiolid squid-*Vibrio* symbiosis will provide a window as to how mutualistic bacteria evolve cooperative mechanisms in a complex beneficial association.

80-4 CHEJANOVSKI, ZA*; KOLBE, JJ; Univ. of Rhode Island; *zchejanovski@gmail.com*

Mechanisms underlying increased body size in lizards due to urbanization and urban predators.

Human-induced environmental change is currently impacting animal populations on a global scale. For example, the rise and spread of urban areas has drastically altered the environmental conditions experienced by organisms inhabiting cities. These novel conditions may promote change in key phenotypic traits of urban wildlife in order to increase fitness. Conversely, certain traits may remain unchanged if they are constrained (e.g., through genetic correlations with other traits) or already sufficient for persistence under these new conditions. Previous work in southeast Florida has shown that brown anoles (*Anolis sagrei*) from urban environments are larger (i.e. snout-vent length) compared to conspecifics from nearby natural habitats. Additional work has revealed a positive relationship between anole body size and the abundance of its predator (i.e., the curly-tailed lizard, *Leiocephalus carinatus*). However, the mechanism(s) producing these patterns are unknown. To address this, we presented tethered brown anoles of varying sizes (i.e., SVL) to curly-tailed lizards in the field to assess whether larger anoles have a survival advantage over smaller ones. Indeed, smaller anoles were attacked at shorter latencies compared to larger ones. We are currently conducting a common garden experiment to determine whether body size differences among anoles from natural, urban, and urban with predator environments are genetically based. Urbanization is predicted to intensify in the coming decades and we must therefore work to characterize how urban areas influence animal communities to minimize declines in biodiversity.

60-3 CHELINI, MC*; YEAGER, J; BROCK, K; EDWARDS, DL; University of California, Merced; *mcchelini@gmail.com*

Ecological Adaptations Drive Diversity in Degree of Sexual Size Dimorphism in the Common Side-blotched Lizard, Uta stansburiana

Sexual size dimorphism (SSD) is typically associated with a balance between sexual selection through male-male competition and natural selection through female fecundity benefits. In species where females and males make different uses of their habitat, SSD can also be due to sex-specific ecological adaptations to the environment. The evolutionary drivers of sexual dimorphism are unfortunately often assumed to reproductive in nature, and the relationship between sexual dimorphism and ecological adaptations is rarely explored. Here, we test the hypothesis that sexual size dimorphism in the lizard *Uta stansburiana* is at least partially driven by ecological adaptations. Populations of this polymorphic lizard differ in number of males color morphs, as well as in degree of SSD. By collecting morphological and ecological data on males and females from 14 populations of *U. stansburiana* distributed across the southwestern US, we show that environmental factors influence female and male size differently, resulting in intraspecific differences in the degrees of SSD. By building a population-level phylogeny of this species, we have also shown that although genetic similarities explain some of the variation observed between populations, a proportion of the variance encountered is better explained by environmental conditions than by number of male morphs or by phylogenetic relationships alone. Our results highlight that natural selection through ecological adaptations are a long-ignored potential driver of sexual dimorphism in a classic study system of sexual selection, and urge future studies to go beyond the relationship between sexual dimorphism and reproductive benefits.

97-2 CHENEY, JA; STEVENSON, JPJ; DURSTON, NE; USHERWOOD, JR; WINDSOR, SP; BOMPHREY, RJ*; Royal Veterinary College, UK, University of Bristol, UK; *rbomphrey@rvc.ac.uk*

Avian gliding flight: wing configurations in and out of ground effect

The numerous degrees of freedom afforded by the avian wing and its deformable feathers provide birds with impressive flight capacity. Skeletal movements influence the gross aerodynamic shape of the wing, whilst feather bending and interaction allow both continuous and discontinuous surface possibilities. The avian flight control system intricately balances its functional morphology to produce aerodynamic surfaces that can cope with dynamic environments. This work focuses on understanding the selection of wing morphology for two fundamental and repeatable flight test cases. We investigated quasi-steady gliding *in* and *out of* ground effect for a barn owl (*Tyto alba*), tawny owl (*Strix aluco*), goshawk (*Accipiter gentilis*) and tawny eagle (*Aquila rapax*) over multiple flight trials. Each flight was captured with twelve high-speed cameras and a marker-based motion tracking system. This enabled 3D reconstruction of the upper and lower wing surfaces, supplemented by trajectories of key anatomical features (body and feathers). Application of the reconstruction method to a bird-sized calibration object showed that 95% of points were within 3mm of the nominal geometry, with a modal error of 0.2mm. Most flights take place at near-constant horizontal velocity through the measurement region. There is little difference in the measured glide angles (and hence the lift-to-drag ratios for steady flight) between the two flight cases, which is unusual given the aerodynamic enhancements normally conferred by proximity to the ground. We present the associated wing morphologies, including spanwise distributions of wing thickness, camber and twist.

122-5 CHEU, A.Y.*; BERGMANN, P.J.; Clark University; *acheu@clarku.edu*

Basilisk Olympics: Multiple modes of locomotion influences the degree of functional constraint in a trait

Organisms possess suites of traits that aid them in carrying out ecologically-relevant tasks for their survival. The relationships between phenotypic traits and tasks are typically very complex where many different phenotypic traits often interact to carry out a variety of performances, a concept known as many-to-many mapping. By quantifying the complex form-function relationships between many traits and many tasks, we are able to better understand how this contributes to varying levels of functional constraint within a suite of traits. However, in previous form and function relationship work, only two measures of performance have been considered at a time. Here we look at four different modes of locomotion: bipedal running, jumping, swimming, and climbing in brown basilisk lizards, *Basiliscus vittatus*. By considering greater numbers of performance measures, we are able to examine how trade-offs, facilitations, and one-to-one relationships can constrain a given phenotypic trait simultaneously. To do this, we utilize the F-matrix, a statistical model used to compare multiple phenotypic traits to multiple performance measures. The F-matrix approach also allows us to quantify the degree to which trade-offs and facilitations appear in a system and predict which traits are most functionally constrained and, therefore, are least evolvable. We find that increasing the number of performance measures can either decrease or increase the level of functional constraint and overall evolvablity within the functional system.

47-6 CHIN, B/A*; PLACE, S/P; California State University, Sonoma; *chinb@sonoma.edu*

Characterizing the role of DNA methylation patterns in the California mussel, Mytilus californianus

Two populations of marine mussel, *Mytilus californianus*, reside along the Oregon coast and experience marked differences in environmental and oceanographic conditions despite being only 65km apart. Previous research suggests these populations experience high levels of gene flow resulting in genetically homogeneous populations. However, recent growth and DNA methylation data from long-term reciprocal transplant experiments suggest these mussels may establish metabolic patterns that allow for optimal growth under oceanographic conditions specific to the region they first settled and that DNA methylation may explain these locally adapted phenotypes. In invertebrates, hypermethylation of genes is predicted to protect housekeeping genes from variation, while hypomethylation in inducible genes are predicted to allow for variation of genes; thus allowing for locally adapted phenotypes or physiological plasticity. We used an in silico approach to predict the expected level of DNA methylation in housekeeping and inducible genes from these two mussel populations. Our data confirms these DNA methylation patterns previously seen in other invertebrates. Secondly, we performed digital gene expression analysis to identify differentially expressed genes between the two populations and found genes related to two biological functions, immune response and DNA repair, to be enriched in mussels from one population. From our in silico analyses, several genes associated with these biological functions display high CpG O/E ratios, suggesting they are subject to low levels of methylation and potentially greater variation in expression. We are currently working to identify differences in methylation status for genes that show differential expression between populations.

38-3 CHIN, DD*; RODERICK, WRT; WANG, YW; CUTKOSKY, MR; LENTINK, D; Stanford University; *ddchin@stanford.edu*

Preparing for Takeoff and Sticking the Landing: At the Interface of Flight and Surface Locomotion

The outdoor world is covered in a wide range of surface textures and geometries, from rough tree bark to smooth building exteriors, which provide birds with useful infrastructure for perching. However, we do not yet know the fundamental principles behind the mechanisms and strategies that enable birds to land and take off from such diverse surfaces. To study these behaviors in detail, we made high-speed recordings of Pacific parrotlets taking off and landing from instrumented perches with a wide range of surface properties and diameters. We then used these recordings to develop kinematic and dynamic models, which provide insight into the control strategies that enable these maneuvers as well as how the feet conform to and grasp different structures. By further integrating these results with claw and foot measurements, summarized by models, we can better understand the claw/surface interaction involved in clinging to both natural and man-made surfaces. This insight into the biomechanics and behavior of how birds take off and land on a variety of surfaces can also inform the design of more robust and versatile perching mechanisms for aerial robots.

106-5 CHINN, SM*; MONSON, DH; TINKER, MT; STAEDLER, MM; CROCKER, DE; Sonoma State Univ, USGS, UC Santa Cruz, Monterey Bay Aquarium; *sarahchinn@gmail.com*

Lactation and Resource Limitation Affect Stress Responses, Thyroid Hormones, Immune Function and Antioxidant Capacity of Sea Otters (Enhydra lutris)

Lactation is the most energetically demanding stage of reproduction in mammals. Increased energetic allocation toward current reproduction may result in fitness costs. Trade-offs during lactation may include reduced energetic allocation to cellular maintenance, immune response and survival and may be further influenced by resource limitation. As the smallest marine mammal, sea otters (*Enhydra lutris*) have the highest mass-specific metabolic rate necessitating substantial energetic requirements for survival. Caloric insufficiency during lactation is reflected in the high numbers of maternal deaths from End-Lactation Syndrome in the California subpopulation. We investigated the effects of lactation and resource limitation on maternal stress responses, metabolic regulation, immune function and antioxidant capacity in two subspecies of wild sea otters (*E. l. nereis* and *E. l. kenyoni*). Lactation and resource limitation were associated with reduced glucocorticoid responses to acute stress. Corticosterone release was lower in lactating otters. Cortisol release was lower under resource limitation and suppression during lactation was evident under resource limitation. Lactation and resource limitation were associated with alterations in thyroid hormones. Immune responses and total antioxidant capacity were not reduced by lactation or resource limitation. These data provide evidence for allocation trade-offs during reproduction and nutrient limitation. Income-breeding strategists may be especially vulnerable to the consequences of stress and modulation of thyroid function when food resources are insufficient to support successful reproduction and may come at a cost to survival, and thereby influence population trends.

P1-55 CHISHOLM, KL*; PAPATHEOFANIS, CF; REZK, CA; WILTSE, MS; WEN, AH; SMODLAKA, H; HIGHAM, TE; SCHMITZ, L; Scripps College, Pitzer College, WUHS Pomona, UC Riverside, Claremont McKenna, Scripps, and Pitzer Colleges; *kchishol3188@scrippscollege.edu*

Low Retinal Convergence in the Nocturnal Leopard Gecko, Eublepharis macularius

The eye is an ideal model for studying the mechanisms that control the evolution of complex traits in changing environments. Geckos are an exemplary vertebrate group to investigate this question, because they have undergone many evolutionary transitions between diel activity patterns, exposing them to different light levels throughout their history. One way to modify the light sensitivity of an eye is to modulate the convergence of photoreceptors onto retinal ganglion cells: the higher the convergence, the brighter the image. We therefore predicted nocturnal geckos to have high convergence, similar to other vertebrates active in dim light. We examined retinal ganglion cell and photoreceptor densities in the nocturnal leopard gecko (*Eublepharis macularius*). After isolating and wholemounting the retina, we stained ganglion cells with cresylviolet and mapped cell topography using R. Retinal ganglion cells were distinguished from displaced amacrine cells by anatomical criteria. Photoreceptors were visible due to pigmented epithelium outlining individual photoreceptors, a finding confirmed by H&E staining and immunohistochemistry. Our results reveal a surplus of retinal ganglion cells. The low convergence is consistent across the entire retina, as the topographic distribution of ganglion cells and photoreceptors is similar across the retina, with an area centralis nasal to the optic nerve. Hence, high retinal convergence does not contribute to light sensitivity in the leopard gecko. Instead, large receptive fields and high light sensitivity are achieved by increasing photoreceptor size. Future comparative studies are required to test whether this is a pattern found across all geckos.

36-4 CHONG, B*; AYDIN, YO; HUBBARD, AM; RIESER, JM; WU, Y; GONG, C; RANKIN, JW; MICHEL, K; NICIEZA, A; HUTCHINSON, JR; GOLDMAN, DI; CHOSET, H; Carnegie Mellon University, Georgia Institute of Technology, GT, GT, CMU, Royal Veterinary College, RVC, University of Oviedo; *baxichong8@gmail.com*

Geometric mechanics provides insight into spine-limb coordination for locomotion of a sprawled-postured tetrapod

We use geometric mechanics (e.g. Hatton et al, PRL, 2013) to understand the coordination patterns between limb movements and back bending during the locomotion the fire salamander (*S. salamandra*). To characterize the footfall patterns as the salamanders walked on a bed of level sand (0.3 mm diameter glass particles), we used Hildebrand's gait diagram, which classifies gaits based on two parameters: duty factor and leg phase shift (Science,1965). Our geometric mechanics model assumes that each limb has two degrees of freedom and one degree of freedom for body bending in the lateral plane. To model the interaction of the feet with the ground (assuming little belly drag) we used granular resistive force theory (Zhang & Goldman, 2014) with new drag and intrusion force relations. Natural variation in gait (among 3 individuals tested) enabled comparison of experiment and theory at different points in the Hildebrand space. One animal used a lateral sequence tripod gait (duty factor 75%, leg phase shift 25%) with a phase offset (defined as the phase between the peaks of front right leg angle and body angle) of 89 deg (with ~20% variation) in good accord with theoretical prediction (88 deg). The second animal used a diagonal gait (duty factor 75%, leg phase shift 50%) with a phase offset of 43 deg (theoretical prediction 45 deg). The third animal tested used a lateral sequence diagonal couplet gait (duty factor 75%, leg phase shift 37.5%) displaying a phase offset of 66 deg (theoretical prediction 67 deg). The theory (and a morphologically similar robophysical salamander model) also allows study of gaits and phase shifts that are not observed in the animal, revealing disadvantages of improper phasing (or no body bending at all).

47-2 CHOU, H*; FUNK, DH; JIMA, DD; BUCHWALTER, DB; North Carolina State Univ., Raleigh, Stroud Water Research Center, Avondale; *hchou2@ncsu.edu*

The Daily Scorcher: Life History and Transcriptomic Responses of the Mayfly Neocloeon triangulifer to Chronic Daily Forays into Uncomfortably Warm Temperatures

In freshwater ecosystems, species typically experience fluctuating diurnal thermal regimes. To determine the life history and transcriptomic response of a mayfly to chronic daily forays into uncomfortably warm temperatures, we first determined chronically stressful temperatures by rearing *N. triangulifer* for full life cycles under static conditions. We then used this information to create "controls": daily mean temperature (22°C) oscillating between 19.5°C and 24.5°C and "challenge" treatments: daily mean temperature (26°C) oscillating between 23.5°C and 28.5°C. Life history outcomes did not differ between static and fluctuating temperatures at 22°C, whereas at 26°C, fitness was reduced in oscillating conditions relative to static. RNAseq analysis was conducted on whole larvae sampled at the daily extremes of each variable thermal regime. We found very few genes differentiated ($P<0.1$, $FDR<0.05$) within the "control" group, whereas 93 genes were differentiated within the "challenge" group. To assess whether larvae recover from daily forays into challenging temperatures, we compared expression patterns between samples of 23.5°C (cold portion of the "challenge") and 24.5°C (warm portion of the "control") and found 334 genes were differentially expressed. Biological function and pathway analyses are currently underway. Our results suggest that larvae do not fully recover from chronic (daily) transient exposures to challenging temperatures.

96-5 CHOU, A*; CRONIN, TW; University of Maryland, Baltimore County; *achou2@umbc.edu*

An additional ellipsoid body-like neuropil in the stomatopod central complex?

Stomatopod crustaceans, also known as mantis shrimp, are behaviorally complex marine arthropods. They possess unique eyes with independent movements and multiple analytical pathways. Streams of visual information from the eyes are thought to be integrated in the central complex (CX) for behavioral control. The CX is a multisensory integrator implicated in behavioral action selection, spatial orientation, path integration, and visual memory. In dicondylic insects, the CX is composed of four midline neuropils: the protocerebral bridge (PB), the fan-shaped body (FB), the ellipsoid body (EB), and the paired noduli (NO). Together, the FB and EB comprise the upper and lower divisions of the central body (CB). While the CX of insects and crustaceans share common developmental origins, the crustacean CX is more structurally simple. It is composed of a small PB sitting above a thin, bistratified CB. The stomatopod CX is an exception to this pattern. A recent student shows the stomatopod CX comprises of a well-developed, modular PB, a bi-layered CB, and a pair of noduli-like neuropils structures thus far found only in pterygote insects. While the upper and lower divisions of the stoamtopod CB are thought to be equivalent to the insect FB and EB, respectively, here we report a previously undescribed neuropil in the stomatopod Neogonodactylus oerstedii. Immunostaining with anti-DC0 and anti-synapsin reveal a bulbous neuropil posterior to the bi-layered stomatopod CB. This pattern of immunoreactivity is notably similar to that of the EB of insects such as cockroaches or fruit flies. These data imply that the bi-layered CB of stomatopods and other crustaceans is more comparable to the insect FB alone.

P1-99 CHRISTENSEN, JM*; LYN, S; PARKER, G; VANDENBROOKS, JM; Midwestern University; *jchristensen19@midwestern.edu*

Rearing oxygen affects wing vein morphology and flight performance in Drosophila melanogaster

Variation in atmospheric oxygen over geologic time has been hypothesized to affect the evolution and physiology of insects. However, the insect fossil record is composed of mostly isolated wings, which presents challenges in interpreting the data. Therefore, understanding how wing morphology varies with atmospheric oxygen is a critical step in addressing these hypotheses. Wing veins contain tracheae that deliver oxygen to the wing and may control the patterning and morphology of the veins during development. It has previously been shown that rearing oxygen is inversely correlated with tracheal widths in the legs and bodies of insects, but wing veins remain unexplored. Therefore, we hypothesized that wing vein diameters should be inversely correlated with rearing oxygen. To this end, *Drosophila melanogaster* were reared from egg to adult under three different oxygen concentrations: 12%, 21%, and 31%. The wings were then dissected and imaged using a mechanical stage mounted on an inverted microscope at 40x magnification. Wing area, wing vein diameters, and wing vein lengths were all measured using ImageJ. Wing area and wing vein diameter both were inversely correlated with rearing oxygen. In a second experiment, flies were again reared in three different oxygen concentrations and then flown in all three oxygen levels to test the effect of these changes in wing morphology on flight performance. Flies performed best in the oxygen level they were reared under indicating changes in wing morphology are adaptive in response to oxygen variation. These results point to the ability to use wing morphology in the fossil record to interpret evolutionary changes. Additionally, this suggests that wing vein diameters could potentially act as a proxy for atmospheric oxygen over geologic time.

50-4 CHUNG, AK*; COX, CL; COX, RM; Georgia Southern University, University of Virginia; *ac10578@georgiasouthern.edu*

Age and Tissue Specificity of Sex-biased Gene Expression and the Development of Sexual Dimorphism

Males and females of sexually dimorphic species must produce distinct phenotypes from a single, shared genome, which can be accomplished by differential gene expression between the sexes. Sex-biased gene expression is predicted to increase during ontogeny as sexes transition from monomorphic juveniles to sexually dimorphic adults. However, differential gene expression should be specific not only to sex but also to tissues that are important for the development of dimorphic traits. Previous research in other model and non-model organisms has focused on sex-biased gene expression of adults within a single tissue, overlooking how sex-biased gene expression may change with age and vary across tissues. Thus, studying sex-biased gene expression across developmental stages and different tissues is important for a complete understanding of sexual dimorphism. Using high-throughput RNA sequencing methods, we generated whole transcriptomes of the brain, muscle, and liver from brown anole lizards (*Anolis sagrei*) of ages 1, 4, 8, and 12 months to study sex, age, and tissue specificity of gene expression. Prior work has shown that hepatic gene expression of brown anoles diverges in the sexes between 7 and 14 months, during the development of sexual dimorphism. Comparing this finding with other tissues and an increased number of age points will provide a more complete picture of sex-biased gene expression. This study is crucial for understanding not only how ontogenetic changes in sex-biased gene expression lead to sexual dimorphism, but also how variation in sex-biased gene expression across tissues facilitates the evolution and development of sexual dimorphism.

S9-11 CHUNG, DJ; SPARANGA, GC; CHICCO, A; SCHULTE, PM*; University of British Columbia, University of Colorado, Denver, Colorado State University; *pschulte@zoology.ubc.ca*

Thermal Acclimation and Intraspecific Variation in Fundulus heteroclitus Mitochondrial Performance and Lipid Remodeling is Consistent with Homeoviscous Adaptation.

Mitochondrial performance is dependent on the action of proteins embedded within the inner mitochondrial membrane, and thus the composition of the mitochondrial membrane is likely to be a key determinant of mitochondrial function and whole-organism performance. Because of the profound effect of temperature on the properties of membranes, we predicted that thermal acclimation and local adaptation of populations to different temperatures would be associated with variation in mitochondrial membrane lipids and mitochondrial respiratory capacity. We assessed this prediction with northern and southern subspecies of Atlantic killifish (*Fundulus heteroclitus*) acclimated to a range of temperatures using high-resolution lipid analyses to measure mitochondrial phospholipid headgroups and headgroup-specific fatty acid remodeling, and high-resolution respirometry to assess mitochondrial respiratory capacity. Acclimation resulted in compensatory changes in mitochondrial respiratory capacity in both subspecies. In addition, northern *F. heteroclitus* exhibited greater mitochondrial respiratory capacity across acclimation temperatures, which is consistent with previously observed subspecies differences in whole-organism aerobic metabolism. Mitochondrial phospholipids were altered following thermal acclimation and differed between subspecies. These effects were largely driven by increased polyunsaturated fatty acid content, consistent with homeoviscous adaptation. These results support a role for mitochondrial function in the response to thermal stress and provide evidence of lipid remodeling as a mechanism regulating these changes.

81-2 CIERI , RL*; FARMER, CG; University of Utah; *bob.cieri@gmail.com*

Computational fluid dynamics modeling of pulmonary airflow in monitor lizards (Varanidae)

Understanding the biomechanical basis of avian unidirectional pulmonary airflow, a condition where lung gases travel in the same direction through most of the airways and throughout the respiratory cycle, has long been of interest to scientists. Recent work has revealed a wide phylogenetic distribution of this trait, beyond the confines of Aves, to include crocodilians, green iguanas, and monitor lizards, and has raised new questions about the underlying fluid dynamical phenomena occurring in unidirectional lungs. Advances in computational fluid dynamics, a technique where patterns of flow are simulated from prescribed boundary conditions by laws of fluid motions, provide a powerful tool to study airflow through these complex and fascinating structures. In this study, computed tomography scans were segmented into a detailed computational mesh, representing the major and minor airways of the savannah monitor, *Varanus exanthematicus*. Flow was simulated through these airways in two ways: 1) in a dynamic simulation, where air flowed into and out of the lung domain through a static tracheal inlet that was driven by expansion and contraction of the lung domain. 2) steady state flow with the caudal part of the lung serving as an outlet or inlet respectively. Simulations were carried out in open-source software on an 80-processor computing cluster. The model shows unidirectional pulmonary airflow in many regions of the lung, and reveals airflow patterns in chambers that are too small or are inaccessible to empirical study. The results of this study indicate that many aspects of the flow are similar between the dynamic and static models. Further computational modeling can be used to test hypotheses regarding unidirectional flow, such as the role of internal lung partitions and the pattern of lung motion during ventilation.

P2-124 CLARDY, TR; King Fahd Univ. of Petroleum and Minerals; *tclardy@kfupm.edu.sa*

Photophore structure in larval Vinciguerria mahabiss Johnson and Felts 1984 (Stomiiformes: Phosichthyidae)

Bioluminescence, the biological production of light, is a common communication strategy in many mesopelagic and bathypelagic fishes. Bioluminescence in fishes takes place inside specialized glandular cutaneous organs called photophores. The number, size, placement, and structure of photophores varies greatly across fishes and likely has evolved independently multiple times. In this study, the ultrastructure and microstructure of photophores in *Vinciguerria mahabiss*, a species of Phosichthyidae endemic to the Red Sea, is described. The volume of each of the 144 photophores from 5 juvenile *V. mahabiss* was measured. The size-corrected volumes, standardized by head length, show clear differences in photophore size across body regions with the post-orbital, lateral, and post-anal photophores the smallest and the sub-orbital photophore the largest. Photophores were sectioned at 5 microns and double stained with eosin/hematoxylin to examine their microstructure. The microscopic photophore structure shows a standard Stomiiformes arrangement with a rounded photogenic chamber and a thick outer lens. The possible functional significance of photophore arrangement and structure in *V. mahabiss* are discussed.

34-7 CLARK, EG*; KANAUCHI, D; KANO, T; AONUMA, H; ISHIGURO, A; Yale Universiity, Tohoku University, Hokkaido University; *elizabeth.g.clark@yale.edu*

Insights into the Control Setup underlying the Resilient Decentralized Locomotion of Brittle Stars

Brittle stars (Class Ophiuroidea, Phylum Echinodermata) have evolved a unique form of rapid, omnidirectional locomotion which requires them to coordinate their five arms and over 1,000 skeletal elements without a brain. When an arm is lost, they not only regenerate it, but function with near-equal locomotory facility using the remaining arms while the lost arm regrows. The control setup underlying this resilient, decentralized locomotion strategy is unclear, and has pertinent applications to the engineering of adaptive robots. The ophiuroid nervous system consists of a nerve ring at the center of the body that connects to a nerve that runs along the length of each arm. Suggested functions for the nerve ring range from a centralized processing unit to a simple connection between adjacent arms. We tested the function of the ophiuroid nerve ring through a series of experiments comparing locomotory behavior with and without intact nerve ring connections. The number and position of places where the nerve ring was severed were varied. Our observations show that the nerve ring connection is crucial for transmission of information between arms, but animals with breaks in the nerve ring continue to exhibit coordinated locomotion through shifts in the gait using the arms that remain connected. The next step for our research team is to test our hypothesized control setup through mathematical and robotic modeling, with the aim of informing the future design of resilient decentralized robots.

6-5 CLARK, AJ*; UYENO, TA; College of Charleston, Valdosta State University; *clarkaj@cofc.edu*

How Jawless Fishes Bite with "Rasping Tongues"

The cylindrical jawless feeding apparatuses (JFA) of hagfish and post-metamorphic lamprey, which include toothplates, associated muscles and cartilages, are traditionally referred to as "rasping tongues" due to the complex arrangements of muscle fibers that power the cyclic protraction-retraction motions of the toothplates. These toothplates are highly effective at grasping and piercing tissues, thus their motions might be more appropriately referred to as biting. Most biting systems include a pair of occluding tooth-bearing beams (e.g. jaw bones) connected by sturdy, compression-resistant joints. When employed, the biting system forms a closed kinematic loop, in which the reaction forces of those applied between the teeth are transmitted through the jaw joint. "Biting" can be a problematic term for jawless feeding systems because the retracting toothplates lack an obvious opposing element resembling an upper jaw; Toothplates applied to a surface without such opposing resistance, should simply push the animal away from the surface. This study 1) demonstrates how hagfish and lamprey supply their JFAs with a closed kinematic loop and thus implement true biting, and 2) compares structural and functional traits of the JFA in both taxa. Our survey of the literature and our own gross and histological anatomical descriptions indicate that hagfish and lamprey furnish an opposing element and close the kinematic loop in radically different ways: Lampreys use the adhering suction of their oral discs to counter the force of their rasping tongue whereas hagfish employ whole body knots to generate the required leverage.

57-3 CLARK, MI*; AKOPYAN, M; BRADBURD, GS; VEGA, A; ROBERTSON, JM; California State University, Northridge, Cornell University, Michigan State University, AMBICOR; *meaghan.clark.90@my.csun.edu*

Evolutionary history of red-eyed treefrogs (Agalychnis callidryas) in a hotspot of color pattern diversity

Linking phenotypic variation to underlying genetic diversity contributes to a better understanding of how evolutionary forces affect natural populations. We investigate the genetic structure and evolutionary history of red-eyed treefrogs (*Agalychnis callidryas*) occupying six regions along the Pacific coast of Costa Rica, where a phenotypic cline extends from the north (orange legs) to the south (purple legs), with intermediate color patterns in central regions. Patterns of color variation in intermediate central regions could be explained by the retention of ancestral color polymorphism, or by hybridization between divergent populations that meet at secondary contact zones. Comparison of RAD-sequencing and color pattern data shows patterns of genetic isolation by distance across color pattern boundaries. We present multiple incongruent patterns of phenotypic and genetic variation, which suggest the possibility of selective pressures acting on color pattern phenotype along the Pacific Coast. Overall our data support color pattern polymorphism due to differential retention of ancestral polymorphism as opposed to recent introgression.

P3-28 CLARK, JM*; SPEISER, DI; Univ. of South Carolina, Columbia; *jamiec@email.sc.edu*

Restoration of visual performance during eye regeneration in the Florida fighting conch (Strombus alatus)

Conch are slow-moving, herbivorous, marine gastropods that possess prominent camera-type eyes at the ends of long, flexible stalks. Compared to the eyes of other gastropods, those of conch are large (up to 1.5 mm in diameter) and have sophisticated optics that include a lens with a graded refractive index. Conch also have a remarkable ability to regenerate eye tissue: after an eye is lost, a new eye will develop to take its place within weeks. Eye regeneration in conch appears to occur rapidly compared to eye regeneration in other gastropods. Despite our knowledge of the complexity and regenerative abilities of the eyes of conch, we know little about the visual responses of these animals either when their eyes are intact or while they are regenerating. Therefore, we measured rates of eye regrowth and tested how visual performance changes during the process of eye regeneration in the Florida fighting conch *Strombus alatus*. We found that rates of eye regrowth were greatest in *S. alatus* between 3-6 weeks following amputation but began to slow down thereafter. We also found that conch with two intact eyes respond consistently to the sudden appearances of objects with angular sizes of 23° or greater. When we amputated either one or both eyes from 24 conch and recorded the behavioral responses of these animals to visual stimuli once a week for twelve weeks, we found that animals with one amputated eye regained normal visual performance after five weeks whereas conch with two amputated eyes exhibited normal visual performance after seven weeks. Studying the restoration of visual performance during eye regeneration in conch may help us understand how a regenerating sensory system reconnects with an intact nervous system.

82-5 CLARK, RM*; TREIDEL, LA; MCCUE, MD; ZERA, AJ; WILLIAMS, CM; Univ. of California, Berkeley, Saint Mary's University, Univ. of Nebraska-Lincoln; *r11clark@gmail.com*

Energetics of a Life-History Trade-Off in the Wild

A wide array of organisms possess dispersal polymorphisms, where some individuals invest in the physiological machinery needed for dispersal while others lacking this capability instead allocate resources toward alternate life-history traits such as increased reproduction. While the biochemical basis underlying such polymorphisms has been extensively studied in selected insect laboratory populations, actual metabolic dynamics in wild populations are not as well understood. To assess the extent to which laboratory findings correspond to field dynamics, we measured whole-animal metabolic rates and lipid oxidation rates for lab-reared and field-caught dispersal and reproductive morphs in wing-dimorphic *Gryllus* crickets. All measurements occurred at 27 &degC. We found that the dispersal and reproductive morphs maintained comparable mass-specific metabolic rates, but metabolic rates were higher in lab-reared as compared to field-caught crickets. When reared in the laboratory, the dispersal morph was also able to sustain correspondingly greater rates of lipid oxidation. In contrast, no morph differences in lipid oxidation were observed in field-caught crickets. These findings support the conclusion that realized dispersal capability in wild populations can often be strongly constrained by local environmental conditions.

P3-238 CLARK, AD*; BEATTY, AE; SCHWARTZ, TS; Auburn University; *adc0032@auburn.edu*

Exploration of the Insulin/insulin-like Signaling Pathway in Non-Model Organisms via Primary Culture Experiments

Insulin-like growth factors (IGFs) are key peptides hormones in the Insulin and Insulin-like signaling (IIS) pathway, a pathway required for growth, metabolism, and reproduction. IGFs and other key components of the IIS pathway are highly conserved across vertebrate lineages including reptiles, but there are still gaps in our knowledge about the specific functions of members of the IIS pathway in reptiles. Primary cultures are virtually non-invasive study systems that provide models of naturally functioning cells or tissues from donor organisms, although this method is not widely used in non-model organisms. Here we describe the establishment of primary fibroblast cultures from brown anole (*Anolis sagrei*) tail tips and their use in experiments to determine the functional roles of IGF1 and IGF2 hormones in cellular growth and proliferation in a reptile system. Species-specific IGF hormones were expressed in a bacterial system and purified for use in experimental treatments. Low-serum treatment media containing brown anole IGF1, brown anole IGF2, green anole (*Anolis carolinensis*) IGF1, whose amino acid sequence of the binding region differs from brown anole, TGFb as a positive growth control, or media without growth hormones were added to cells. Cellular proliferation was indirectly assessed via MTT assay 24 hours, post exposure to treatment medium. IRS-1 mRNA levels were quantified via qPCR at time points of 2 and 4 hours. Results on the effects of the treatments will be discussed with implications for the use of cell culture in non-model organisms to understand the function and evolution of molecular pathways, such as the IIS.

P1-200 CLAVIJO-BAQUET, S*; CAVIERES, G; GONZALEZ, A; CATTAN, P; BOZINOVIC, F; Laboratorio de Etología, Ecología y Evolución, IIBCE, Montevideo, Uruguay, CAPES, Pontificia Universidad Católica, Santiago, Chile, Facultad de Ciencias Veterinarias y Pecuarias, Santiago, Chile; *sclavijo@bio.puc.cl*
Temperature Effects in Thermal Tolerance of the Chagas Disease Vector, Triatoma infestans.
The relationship between climate change and the increasing rate of emergence of infectious diseases is one the most formidable ecological problems of our time. In this sense, the vector-borne diseases are especially susceptible to climate change due to most disease's vectors are ectotherms, which make them susceptible to temperature changes. In this work, we studied the possible impact of thermal variability on locomotion performance in a Chagas disease vector, *Triatoma infestans*. Individuals from laboratory colonies were randomly assigned to four thermal treatments during 5 weeks (18±0ºC, 18±5ºC, 27±0ºC and 27±5ºC). We quantified the effect of temperature on walking speed on fifth-instars individuals exposed at eight temperatures (from 8 to 42ºC). Maximum velocity (Vmax), temperature optima (To) and performance breath (Tbr) were estimated. We fit linear mixed models for each variable with temperature, body weight and its interaction term as predictor variables. Preliminary results showed that To decreased in individuals acclimated to 18±5 ºC and increased in those acclimated to 27 ±5 ºC. Vmax did not change in individuals acclimated to lower and variable temperatures while temperature variability increased Vmax on 27 ±5 ºC individuals. Regarding to Tbr, it did not change with temperature variability but indeed decreased in individuals acclimatized to lower temperatures. Our results evidence that *T. infestans* could improve thermal performance at higher and variable temperatures as the predicted temperatures by scenarios of climate change. FONDECYT 11160839

43-1 CLAYTON, GV*; KAHN, H; SMITH, NM; DICKERSON, AK; University of Central Florida; *dickerson@ucf.edu*
Mosquito Takeoff Strategies from Horizontal Surfaces
On roughened surfaces, such as those equivalent to the roughness of skin, male and female Aedes aegypti mosquitoes employ a takeoff strategy similar to those witnessed in other Diptera; they initiate their takeoff with a push from mid- and hind-legs. Such a twitch of the legs lasting 15 ms allows tarsi to remain static until the legs reach maximum extent and are drawn inward as the body rises at 0.25 m/s when legs leave the ground under flapping. In contrast, polished surfaces provide little traction to the mosquito pushing with its legs, inducing tarsal slip and decreasing the efficacy of the push. Instead, the vast majority of mosquitoes prefer initiating takeoff from polished surface with a leg strike, in which one or both hind-legs are raised into the air before swinging downward like a golfer's swing and striking the ground at 0.55 m/s. The ensuing reaction force lifts the mosquitoes body skyward at more than 0.5 m/s when legs leave the ground and full flapping commences. We hypothesize mosquitoes select the particular strategy which imparts greater performance by way of maximum stability or efficiency during the first critical wingbeats of flight. We characterize the takeoff kinematics of mosquitoes launching unprovoked from polished and roughened horizontal surfaces using high-speed videography, and rationalize the shift in their takeoff strategy through kinetic considerations.

137-5 CLIFTON, GT*; TAYLOR-BURT, K; Univ. of California, San Diego, Harvard University; *glenna.clifton@gmail.com*
What is a scientist? A large-scale SICB outreach effort focusing on science literacy
A challenge facing K-12 educators is showing that science is not simply memorized facts, but instead is a creative and iterative process of curiosity, investigation, analysis, and communication. To engage students in the process of science while increasing scientist accessibility, we formed the "What is a scientist?" outreach effort (WIAS) in association with the 2017 SICB meeting in New Orleans, LA. While most K-12 curricula include the scientific method, many students graduate unable to critically analyze the strengths and weaknesses of reported science they encounter in daily life. Scientists are uniquely positioned to share real examples of assessing evidence and using the scientific process to discover new knowledge. We designed WIAS as a large-scale, low-cost program with two main goals: (1) help students understand the scientific process and what makes a study credible and (2) generate enthusiasm for science through interactions with research scientists. Over two days, 27 SICB scientists visited 47 middle school classrooms. In total, we reached about 1000 students. The WIAS program consisted of two components. First, scientists described (1) their research question, (2) how they seek answers to that question, (3) how they communicate their findings, and (4) their lives outside of the lab. Second, students worked in small groups to design a taste test study using M&Ms. The visiting scientists challenged the students to determine whether their methodology accurately tested the research question and finished with a group discussion on the limitations of the study and its implications for interacting with science in daily life. Our presentation will include both role-playing examples from the program and a discussion on ways to improve WIAS and implement large-scale outreach.

P2-119 CLIFTON, B*; JAYASWAL, V; JIMENEZ, J; NGUYEN, K; MAGIE, R; YEH, S-D; RANZ, J M; University of California, Irvine, The University of Sydney, National Central University; *bclifton@uci.edu*
Significant Structural and Sequence Variation within a Recent Species-Specific Gene Expansion with an Influence on Sperm Competition: Sdic
Newly evolved genes, genes specific to one or few closely related species, have been proposed as an important class of genetic factors capable of influencing the evolution of sperm competition. Sperm competition is a mechanism of post-copulatory sexual selection in polyandrous species in which sperm from different males compete to fertilize eggs. Despite its evolutionary relevance in shaping male traits, the genetic mechanisms underlying sperm competition remain mostly uncharacterized. The *D. melanogaster*-specific multigene family, *Sdic* (*Sperm-specific dynein intermediate chain*) is a recent expansion of a chimeric gene along the X chromosome that has undergone a selective sweep within the last 3-5 million years, and has been linked to increased sperm competitive ability by attributing higher paternity contribution relative to *Sdic* region knockouts. Using assays mimicking female multiple mating, where the sperm from *Sdic* knockout versus non-knockout males was directly visualized within the female reproductive tract, we find evidence that the previously observed lower paternity contribution of *Sdic* knockout males mirrors a less effective ability to displace sperm previously deposited by earlier-to-mate males. Additionally, through agreement with annotations of state-of-the-art PacBio-Illumina hybrid genome assemblies and qPCR copy number estimates, we show clear signs of copy number and sequence variation across a range of geographically diverse strains. Our results highlight the role of recent gene expansions as possible drivers of sperm competition evolution.

P2-201 CLIFTON, GT*; GRAVISH, N; Univ. of California, San Diego, UCSD; *glenna.clifton@gmail.com*

Large-scale automated tracking of ant running kinematics and foot contact dynamics

Ants have evolved to inhabit and therefore move through diverse habitats, requiring walking, running, climbing and maneuvering. How do ants coordinate limb movements and modulate foot contact under varying locomotion behaviors? Previous research on ant locomotion and foot mechanics focuses on in situ experiments or straight running during one or a few isolated strides. Here, we present a new approach to automatically record, track and analyze ant kinematics and foot contact dynamics across many strides and during non-stereotyped behaviors. Argentine ants, *Linepithema humile* (body length ~2-3 mm, ~3.5 mg), are placed within a darkened enclosure resting on a smooth glass surface illuminated with LEDs from the side. Ants within the field of view are automatically detected and recorded from above and below using two high-speed cameras at 200 fps. The body of each ant is automatically tracked while foot contact timing and area is visualized using frustrated Total Internal Reflection. The above camera has a field of view of ~28x38 mm and reliably identifies contact areas above 0.0003 mm^2. The lower camera provides a detailed view of foot contact with a view of ~4x6 mm and a contact area resolution of 0.0001 mm^2. We record ants reaching running speeds of 60 mm/s (corresponding to 26 body lengths/s) and an instantaneous acceleration of over 450 body lengths/s^2 within a single stride. Most ants employ an alternating tripod gait with a maximum stride frequency of 14 Hz. The hindlimbs generally contact the surface less strongly than the fore- and midlimbs, except while braking or pivoting within a stride. To run along a curve, ants shift the touchdown of the outside forelimb towards the body midline. Findings using this technique can inform legged robot design and control to accomplish diverse tasks.

P3-240 CLOUTIER, R; GRANDE, T*; DUCLOS, K; Univ. of Quebec, Rimouski, Loyola Univ. Chicago, Univ. of Calgary, Alberta; *tgrande@luc.edu*

Modular Organization of the Weberian Apparatus

Adult phenotypes result from dynamic interactions among developmental stability mechanisms (e.g., canalization, morphological integration, modularity) and developmental instability. Among the stability mechanisms, modularity has been targeted as a primary evolutionary developmental component facilitating the evolvability of complex systems. Among the various definitions of modularity (genetic, developmental, morphological, individual, ecological), a module is a network of interacting elements behaving as quasi-independent units, or as semi-autonomous sets of highly correlated traits within larger units. Here, we explore modularity as it pertains to the evolution of the Weberian apparatus, and test if it is a functional, developmental, and/or evolutionary module. The Weberian apparatus, diagnostic of the ostariophysan subgroup Otophysi, is a mechanical linkage (modified anterior centra, neural arches, supraneurals, and pleural ribs) that transmits motion of the swimbladder wall directly to the inner ear. This linkage enables otophysans to hear frequencies up to several thousand hertz and increases sensitivity throughout the frequency range. Based on cleared and double-stained ontogenetic series of larval-juvenile cypriniform fishes, chondrification and ossification sequences of the Weberian apparatus elements were compared in a phylogenetic framework. We show that both chondrification and ossification sequences provide phylogenetic signal, and heterochronic patterns can be identified at various levels. This suggests that the Weberian apparatus evolved from a non-modified vertebral column in a modular framework, and that heterochronic events occurred during the development of various otophysans. These have resulted in the disparity among cypriniforms and extreme specialization in hearing among otophysans.

30-6 CLUBB, BL*; CLARK, AJ; UYENO, TA; Valdosta State University, College of Charleston; *blclubb@valdosta.edu*

Diversity of function in hagfish feeding apparatuses

Hagfish use a poorly understood feeding apparatus mechanism to protrude and retract a dental plate for rasping chunks of tissue from prey for ingestion. Retraction is achieved by activating a complex soft tissue mechanism found in the posterior half of the feeding apparatus. In this study, we describe the anatomy of this muscular hydrostat by examining the muscle and connective tissue fiber organizations in the feeding apparatuses of nine Pacific (*Eptatretus stoutii*) and six Atlantic (*Myxine glutinosa*) hagfishes. Paraffin histological techniques were used to prepare serial sections. Structural components were manually segmented from these digitized sections and fitted to high-resolution 3D scans (Arctec Space Spider) of the whole feeding apparatus. Our analysis of the soft tissue fiber orientations allowed us to develop a number of functional hypotheses: (i) The tubulatus muscle is not a simple sheath formed of circumferential muscle fibers as previously reported. It is a unique tubular muscle with bi-pinnate muscle fiber orientations that originate from a longitudinal dorsal tendon and insert on a ventral one. Activation may cause the muscle to become longer and skinnier and also cause the dorsal and ventral surfaces to shear relative to each other. (ii) The clavatus muscle includes longitudinal muscle fibers that may generate direct force used in dental plate retraction. (iii) Activation of the complex fiber organization of the perpendicularis muscle likely causes the posterior end of the clavatus to deform laterally and function as a stopper knot to prevent the clavatus from sliding through the tubulatus. While electromyographic recordings of active muscles have been unsuccessful, video recordings of preliminary electrostimulation experiments confirm these functions.

P3-162 COHEN, KE*; HERNANDEZ, LP; The George Washington University ; *karlyelizabeth13@gmail.com*

Morphological ontogeny of the epibranchial organ of Hypophthalmichthys molitrix (Silver carp)

Incredibly invasive Asian carp are destroying ecosystems throughout the United States by outcompeting native species. Their ability to feed so efficiently within eutrophic environments is due to their highly modified gill rakers and complex epibranchial organ. The epibranchial organ is a paired food condensing organ ventral to the neurocranium that has independently evolved multiple times. Ranging in complexity from small slits on the ventral face of the neurocranium to intricate spiraling structures, epibranchial organs are morphologically diverse across filter-feeding fishes. Despite this morphological diversity and broad distribution, little is known of the epibranchial organ's function and development. Here we present data from an ontogenetic series of Silver carp ranging in size from 15-900mm SL detailing how this unique structure develops. Indeed, the epibranchial organ of the Silver carp is morphologically distinct from all that have been previously described. Gill rakers that extend from branchial arches 1-5 are greatly modified as they curve into the body of the epibranchial organ. Throughout ontogeny the epibranchial organ becomes more complex with the gill rakers becoming increasingly incorporated into the overall structure. Increased complexity coincides with histological changes to supporting cartilaginous structures and an increase in innervation. By early juvenile stages, the epibranchial organ is fully functional. The adult epibranchial organ forms a multiple-looped structure that efficiently moves food from the gill rakers to the pharyngeal jaws. This detailed anatomical investigation has yielded a functional hypothesis of the epibranchial organ in Silver carp.

138-2 COHEN, KE*; HERNANDEZ, LP; CRAWFORD, CH; FLAMMANG, BE; The George Washington University , New Jersey Institute of Technology ; *karlyelizabeth13@gmail.com*

Secrets in master filtering: Using µCT and 3D PIV to model Silver carp filter feeding

Invasive Silver carp are thriving in eutrophic environments in the United States due to efficient filter-feeding mechanisms. Like many filter-feeding fishes, Silver carp utilize modified gill rakers to enhance filtering efficiency; however, unlike other fishes, Silver carp gill rakers are fused together to form highly porous, channeled filtering plates. This morphology can capture particles ranging in size from 4-80 µm, which may explain how this species can outcompete other fishes. While descriptive studies exist no work has yet discovered the mechanism behind Silver carp filtration. Here we investigate the hydrodynamics of Silver carp filter feeding using volumetric Particle Image Velocimetry (3D PIV). Fixed gill rakers and 3D models based on 10µm and 28µm µCT scans of adult Silver carp and its sister species Bighead carp were placed in a recirculating flow tank with water flowing across the model in both the anteroposterior and posteroanterior directions. Neutrally-buoyant 50µm nominal size particles were illuminated by a 50mJ-100Hz Nd:YAG pulse laser focused into a 14cm x 14cm x 14cm volume using an optic and mirror system, tracked and processed using V3V software, and resulting vector information was analysed in Tecplot. Using 3D PIV, we tracked particle and fluid interaction from the surface of the gill raker through the various sized pores along the filter. Based on results from multiple PIV studies and morphological analyses, we suspect that the morphology on the outer face of the gill raker plates and the orientation of those openings increases the vorticity of water as it moves across the the gill rakers, accounting for particle capture and retention.

P1-291 COHEN, HE*; KANE, EA; Georgia Southern University; *hc02684@georgiasouthern.edu*

The role of local adaptation on biting performance in Trinidadian guppies

Organisms are faced with many challenges, including predation and resource availability, and these pressures can change across spatial gradients. For example, where predation pressures are low, an increase in population density will increase intraspecific competition for prey resources. However, how these changes in selective pressures lead to local adaptation, particularly in prey acquisition behaviors, needs further exploration. In Trinidadian guppies (*Poecilia reticulata*) a shift in selective pressure toward resource competition in low predation environments has resulted in local adaptation of many traits, including jaw morphology and diet. But whether these changes result in local adaptation of feeding performance remains unclear. Recent work in suction feeding of guppies has shown no difference between populations in feeding performance, suggesting an inability to adapt their feeding system. If selective pressures cause changes in resource use that drive adaptation for feeding, then low predation guppies should have increased biting kinematics compared to high predation guppies. To test this hypothesis we will film individuals from one low/high predation population pair with a high-speed camera while they feed on an agar substrate and measure feeding kinematics to test differences between populations. If gape, intramandibular joint mobility, and time of contact with the substrate are greater in low predation guppies, it would support the hypothesis that guppies are locally adapted to feeding conditions based on their habitat. Otherwise a lack of local adaptation could suggest either an inability to modify feeding performance or that the selection pressure on feeding is relatively weak.

125-3 COLBY, RS; VELOTTA, JP; SCHULTZ, ET*; Univ. of Connecticut, Univ. of Montana; *eric.schultz@uconn.edu*

The presence and evolution of Na^+, K^+-ATPase paralog-switching in a euryhaline fish, the Alewife

The invasion of freshwater from marine habitats prompted extensive diversification of aquatic taxa. Mechanisms permitting this habitat switch can be investigated in extant euryhaline fishes, those that can tolerate a wide range of salinities. Taxa that have undergone genome duplication events are of particular interest as resulting paralogs may contribute to such flexible osmoregulation. Two paralogs of Na^+, K^+-ATPase (NKA), an important ion transporter, occur in the gills of salmonids and are differentially expressed in freshwater (FW) and seawater (SW). These paralogs, NKA α1a and α1b, share a single evolutionary divergence in Salmonids. Our study sought to identify NKA paralogs in an early branching lineage of teleosts, Alewife (*Alosa pseudoharengus*), test their function, and reveal their phylogenetic relationship to those of salmonids. We found NKA paralogs in Alewives and they were differentially expressed in FW and SW. Notably, in landlocked populations of Alewives differential expression is dampened, possibly due to lack of selective pressure favoring SW tolerance. The divergence between the Alewife paralogs predates that in salmonids. This indicates that multiple molecular solutions have arisen for adapting to freshwater within the same gene.

64-5 COLGAN, W/N*; LLOSA, I; HARRIS, L; LEANZA, A; HWANG, A; DEBIASSE, M; RYAN, J; DAVIDSON, B; Swarthmore College, Whitney Lab, Univ. of Florida; *wcolgan1@swarthmore.edu*

Evolution of Chordate Heart Gene Regulatory Networks

The basal chordate *Ciona intestinalis* has been used to untangle the chordate heart gene regulatory network, because of its rapid development and compact genome. A core set of transcription factors including Mesp, FoxF, Hand-like, and GATAa specify heart fate in *Ciona*. The enhancers for these heart genes are characterized, but little is known about the evolution of the heart gene regulatory network. Here we characterize conserved enhancers for *FoxF* and *Hand-like* using the *Corella inflate* genome, which we have recently sequenced. Computational analysis reveled conserved binding sites for upstream transcription factors in both enhancers, however the order, spacing, and orientation was more highly conserved in *FoxF*. Reporter analysis demonstrated that these *Corella* heart enhancers were functional in both *Ciona* and *Corella*. Our results support evolutionary conservation of the *Ciona* heart gene regulatory network and suggest more selective constraint on *FoxF* regulation. This work also provides a framework for the identification of novel *Ciona* heart enhancers based on clustering of conserved transcription factor binding sites.

P1-43 COLLIAS, AA*; KONOW, N; BIEWENER, AA; TIJS, C; University of Massachusetts Lowell, Harvard University, Harvard University; *alexandra_collias@student.uml.edu*

In vivo Muscle Bulging in Relation to Force Production in Rat Medial Gastrocnemius

Limb muscles must produce force to match the mechanical demands of locomotion. As muscle undergoes contractile length changes it remains isovolumetric. Hence, it has been hypothesized that during a high-force contraction muscle bulges in width, as contracting fibers restrict bulging in thickness. By contrast, during a low-force contraction muscles are hypothesized to bulge in thickness as connective tissue stiffness resists bulging in width. This interaction between contractile and connective tissue components of pennate muscles has been shown to govern volumetric constraints *in situ* but is unexplored *in vivo*. The rat medial gastrocnemius (MG) is a unipennate hind limb extensor from which *in vivo* measurements of 3D shape changes and force production can be obtained, allowing us to determine how interactions between muscle width and thickness are shaped by variations in force. We used fluoromicrometry to measure changes in MG width and thickness as rats (N = 5) walked, trotted, and galloped on different treadmill slopes (-20°, 0°, +20°). These nine gait-slope combinations provided a gradient in muscle force and elicited changes in muscle width, thickness, or both. Consistent with our hypothesis, we found bulging in width of the rat MG to nearly double, with a comparable decrease in thickness bulging from the weakest to the strongest contractions. This result indicates that contractile and connective tissues have a balancing role in determining how a pennate muscle resists bulging during variable force contractions *in vivo*. Insight into how 3D muscle bulging is shaped by variations in force production may inform muscle-centered rehabilitation strategies and improve the functionality of prosthetic limbs. (Supported by NIH AR055648).

95-6 COLLIN, R*; DRISKELL, AC; VENERA-PONTóN, DE; BOYLE, MJ; Smithsonian Inst., Panama, Smithsonian Inst., Washington DC, Smithsonian Inst., Fort Pierce; *Collinr@si.edu*

Larval Barcoding of "Minor" Metazoan Phyla in Mega-Diverse Tropical Oceans

Marine biodiversity is poorly documented, particularly the diversity of invertebrate phyla and tropical taxa. In the few cases where it has been employed, DNA barcoding has proved to be an effective tool for detecting taxa which have not been reported as adults from the sampling location. Larval barcoding may be a particularly effective way to sample species with either cryptic or infaunal, soft-bodied adults that may be difficult to collect, as well as those that live in habitats that are difficult to access. Larval barcoding of hemichordates, lophophorates, sipunculans and nemerteans using COI and 16S recovered considerably more species than expected from the Caribbean and Pacific coasts of Panama. In some but not all cases the species can be distinguished on the basis of larval morphology. Few of the species can be assigned to named species from comparisons with sequences in BoLD or GenBank, emphasizing the need for greater effort to sample the benthic soft bodied fauna of the region.

P1-207 COLLINS, CL*; ZIPPAY, ML; Sonoma State University; *collichr@sonoma.edu*

Physiological Performance: Survival of an Invasive Mussel in a Warming Climate

As the climate warms, organisms endure rapid environmental changes and are susceptible to physiological damage that may force them to modify their thermal limits by either shifting their range distributions or being outcompeted by other species. Marine intertidal organisms, specifically, face unique challenges of oxygen limitation and aerial exposure, and it is up to us to understand how they might respond to such conditions and identify important biomarkers that can be used to recognize when an organism may be in jeopardy. Heart rate, is one physiological response, that is well-studied for investigating whole-organismal responses and can explain an organisms critical thermal limit. Furthermore, measurements of enzymatic activity of lactate dehydrogenase (LDH) can infer anaerobic metabolism and be indicative of stress. Thus, we hypothesize that the cardiac performance and subcellular activity of the invasive Mediterranean mussel (*Mytilus galloprovincialis*) will increase as temperature increases in both intertidal and subtidal populations. While exposing subtidal and intertidal mussels to varying temperatures (8-28 °C) at a ramping rate of 4 °C hr^{-1} we measured heart rate every hour and assessed LDH activity for each temperature treatment. For the submerged subtidal population of mussels, preliminary data suggests heart rate slowly increases as seawater temperature increase, while aerial exposed mussels reached a maximum rate at 12-16 °C. These measurements will begin to elucidate whether organisms have the capacity to deal with a changing climate and the physiological mechanisms that drive whole-organismal responses, while providing additional insight into the possible mechanisms that allow this non-native species to tolerate vastly different habitats and outcompete native species.

25-3 COLLINS, KS*; EDIE, SM; BIELER, R; ROY, K; JABLONSKI, D; Univ. of Chicago, Univ.of Chicago, Field Museum of Natural History, Univ. of California, San Diego; *kscollins@uchicago.edu*

Cosmopolitan compromises and tropical trade-offs -latitudinal and morphological "range" in marine bivalves

The taxonomic, functional, and morphological richness of life on Earth is distributed unevenly across the globe, following gradients dictated by both biotic and abiotic factors. The marine Bivalvia, a diverse, widespread clade that in many ways mirrors global shallow-marine diversity patterns, provides a model system for asking questions about spatial patterns in different aspects of richness. Here we analyze morphological patterns and their correlates along a latitudinal gradient. Bivalve shell morphology is a compromise among anatomical constraints, resource allocation strategies, and functional requirements dictated by the environmental conditions the animal lives in. We use 3D micro-CT scans of the rich Florida Keys bivalve fauna (c. 360 species) to quantify internal biovolume, shell-material volume, and internal and external surface areas (including ornamentation), enabling us to evaluate the controls of shell construction, comparing tropical specialists to wider-ranging generalist taxa in a phylogenetic context. Early analyses suggest that Keys-resident taxa that range further north have shells that are thinner relative to their biovolume, less complex external surface areas, and potentially are allocating fewer resources to shell building, than those co-occurring taxa that are restricted to the tropical latitudes. There is also a narrowing of variance of interspecific shell form with increasing northern latitudinal extent - indicating convergence in aspects of morphology regardless of taxonomic affinity, and potentially, trade-offs in morphology for greater environmental range.

67-6 COLLINS, CE*; HUNTER, SL; MCGOWAN, CP; University of Idaho; *cecollins@uidaho.edu*

Biomechanical and performance tradeoffs in bipedal and quadrupedal turning strategies of Desert Kangaroo Rats

Animals propel themselves through physically challenging environments for a variety of tasks including dispersal, feeding, and predator evasion. Animal morphology is critical to meeting the physical demands of locomotion - each task and ecological context correspond with unique requirements. We studied the mechanics of turning in the Desert Kangaroo Rat *Dipodomys deserti*, a bipedal hopping rodent, after observing steady-state turns and rapid turns responding to simulated capture attempts in the field. We coerced and encouraged ten Kangaroo Rats to hop through a 90° turn connecting two straight 1.5m long x 0.2m wide wooden runways lined with thermoplastic rubber to improve grip. Three cameras recording at 200 hz coupled with two force plates recording at 600 hz allowed us reconstruct 3D kinematics and ground reaction forces. We observe that animals use both bipedal and quadrupedal strategies during turns. Preliminary observations suggest quadrupedal turns maybe faster than bipedal turns upon turn entry, but bipedal gaits maybe faster than quadrupedal gaits upon turn exit. This suggests bipedal turns are steadier than quadrupedal turns. Trajectory changes up to 46° are achieved during each bipedal stance while orientation is altered in both stance and swing phases. We discuss the tradeoffs and ecological implications associated with different turning strategies.

P2-123 CONCEPCION, GT*; PELUSO, P; BUMP, P; GONZALEZ, P; LOWE, CJ; ROKSHAR, DS; RANK, DR; Pacific Biosciences, Menlo Park CA, Hopkins Marine Station - Stanford Univ., Pacific Grove, CA, Hopkins Marine Station - Stanford Univ., Pacific Grove, CA, Univ. of California, Berkeley; *gconcepcion@pacificbiosciences.com*

De novo Assembly of the highly heterozygous Schizocardium californicum genome using DNA isolated from Sperm

Efforts to sequence and assemble the genomes of heterozygous organisms have proven difficult with short read approaches. Repetitive DNA structures, structural variation between haplotypes and large genome sizes are limiting factors to achieving highly contiguous assemblies. Other factors paramount to generating a high quality reference are the quality and size distribution of the starting genomic DNA (gDNA) which is often difficult to obtain for non-model organisms due to co-purification of metabolites. Here we demonstrate the utility of long DNA reads to generate a high quality *de novo* reference sequence from a sperm sample isolated from an individual of a highly polymorphic species. High quality gDNA isolated from hemichordate sperm circumvented many common DNA isolation pitfalls. Extracted gDNA was used to generate large insert (>30 kb) libraries for subsequent SMRT Sequencing. Using Pacific Biosciences' Sequel System, the DNA was sequenced and a genome was assembled of approximately 1.6Gb with a contig N50 of ~739Kb. After 2 rounds of polishing with the Arrow consensus calling algorithm, 949 out of 978 (97%) BUSCO orthologs were detected, with 693 (70.9%) of them detected in duplicate, indicating assembly and resolution of different haplotypes in the primary contigs. Animals in the phylum *Hemichordata* have provided key understanding of the origins of the vertebrate body plan. Here we present the highly contiguous de novo assembly and preliminary annotation of an indirect developing hemichordate genome, *Schizocardium californicum*.

26-4 CONITH, A. J.*; KIDD, M. R.; ALBERTSON, R. C.; Univ. of Mass. Amherst, Texas A&M International Univ.; *ajconith@bio.umass.edu*

Evolutionary Consequences of Modularity in the Cichlid Skull

Cichlid fishes exhibit functional decoupling between their oral and pharyngeal jaws allowing independent control of prey capture and processing. By decoupling different structures in the feeding system, it has been proposed that each can evolve independently as separate modules. However, patterns of genetic modularity in the cichlid skull exhibit a trend whereby elements of the upper and lower jaws are under distinct genetic control, and the lower jaw (LJ) shares a common genetic basis with the pharyngeal jaw (PJ). Thus, it remains unclear how modules in the feeding system are patterned and evolve. Here we investigate the degree of evolutionary decoupling among five major components of the cichlid feeding system: premaxilla (PMX), maxilla (MX), LJ, PJ, and the interopercle (IOP) bone. We use Malawi cichlids, and focus on the *Tropheops* species complex given their wide trophic diversity. We hypothesized that the PMX and MX would form separate modules to the LJ, and that the LJ would form a module with the IOP and PJ, a pattern that closely matches the genetic data. We used 3D geometric morphometrics to quantify shape of the feeding system. We then constructed a phylogenetic tree of 165 individuals based on 7593 amplified fragment length polymorphism loci and used phylogenetic regression to test for correlations among feeding structures. We find that the strongest correlations were among shape variables that define depth of the different structures. We also find strong support for correlated evolution between the LJ, IOP and PJ, and not between elements of the upper and lower jaw. Taken together, our data suggests that genetic modularity has a strong influence on patterns of evolution, and that key components of the oral and pharyngeal jaws are coupled at the phylogenetic level.

P2-63 CONN, CE*; MARTINSON, EO; WERREN, JH; KOVACS, JL; Spelman College, The University of Georgia, University of Rochester; *jkovacs@spelman.edu*

Investigating the role of horizontal gene transfer in adaptation to hematophagy

Horizontal gene transfer (HGT) occurs when genetic material is passed laterally across species rather than vertically from ancestors to descendants. It is known to contribute to evolutionary adaptation in prokaryotes, but studies of HGT in multicellular organisms are limited. Despite the paucity of data, horizontally transferred genes (HGTs) have been found in diverse eukaryotes. Some of these genes have been independently acquired in the genomes of organisms with similar ecological niches, suggesting that they may enable adaptive evolution. Studying HGT in parasites is particularly interesting because the association between parasites and their hosts may facilitate the exchange of genetic material. Indeed, HGTs have been identified in diverse parasites from the bacteria, plant, and animal kingdoms. This raises the question of whether certain HGTs have been independently acquired by parasites with similar mechanisms of host interaction. Blood-feeding insects are ideal for addressing this question, because of the vast genetic data available for them and their negative impacts on public health. We asked whether specific HGTs that may facilitate blood-feeding have been independently acquired by hematophagous insects. To address this question, we developed a protocol for conservative identification of HGTs and applied it to parasitic blowfly (*Protocalliphora sialia*). We compared our results with a list of HGTs in mosquitoes, which evolved blood-feeding independently of *Protocalliphora*. Our preliminary results indicate that HGT has occurred in *Protocalliphora*; however, we have not yet identified any HGTs that are also present in mosquitos. Future work should investigate HGT in additional blood feeders to determine the role that this process may play in the evolution of these parasites, some of which present serious threats to public health.

P2-90 CONROY, LP*; ROFF, DA; University of California, Riverside; *lconr001@ucr.edu*

Effects of Mating Status on Female Preference in the Cricket Gryllus firmus

Variation in female state can potentially induce variation in female preferences, affecting the direction and strength of selection on male secondary sexual traits. In short-lived species with limited breeding opportunities, mating status (i.e., virgin or mated) seems likely to govern female preference components like responsiveness (motivation to mate) and choosiness (amount of discrimination). We explored the effect of variation in female mating status on responsiveness and choosiness in the sand cricket (*Gryllus firmus*) in two-choice trials for live male stimuli. We quantified responsiveness as the total number of visits made to both males, and choosiness as the presence or absence of a greater relative preference (higher relative number of visits) to the male with the longer call duration. We found that unmated females were more responsive overall than unmated females, but mated females were choosier about whom they visited, making more visits to the longer calling male. Thus, in this species there appears to be an interaction between mating status and preference such that unmated females might relax, and mated females might strengthen, the amount of selection on male traits.

P3-95 CONVERSE, AK; GENUISE, HM*; THOMAS, P; The University of Texas Marine Science Institute; *heather.genuise@utexas.edu*

Characterization of a Membrane Androgen Receptor's Apoptotic Response in Danio rerio Ovarian Follicle Cells

The breakdown of postovulatory and unovulated follicles relies on apoptosis or programmed cell death and is essential for ovarian remodeling and optimizing the production of viable eggs. Characterization of the apoptotic responses in the fish ovaries is critical for understanding the reproductive physiology of female fish, which can produce thousands of eggs. Previous studies found that testosterone activation of the membrane androgen receptor, ZIP9, induces intracellular zinc transport and apoptosis within Atlantic croaker ovarian follicle cells. In this study, we characterized the androgen-induced apoptotic response of ovarian follicle cells in the model organism zebrafish (*Danio rerio*). We found that testosterone treatment resulted in significantly higher amounts of apoptosis in zebrafish ovarian follicle cells compared to vehicle (ethanol). Furthermore, testosterone treated ovarian follicle cells showed a significant increase in expression of pro-apoptotic genes, *bax* and *p53*. Testosterone treated zebrafish ovarian follicle cells also showed significantly higher levels of intracellular zinc, which is associated with ZIP9 activation. Consequently, our results show that testosterone induces a similar apoptotic response in zebrafish ovarian follicle cells to that seen in the Atlantic croaker. These results suggest that teleosts may share the mechanism for ZIP9 mediation of ovarian cell apoptosis. Future studies should build upon our research by utilizing ZIP9-knockout zebrafish to investigate whether other vertebrates share the mechanism regulating ovarian apoptosis in teleosts.

101-6 COOK, E/G*; LOVERN, M; LEAL, M; Univ. of Missouri, Columbia, Oklahoma State University; *egcrg7@mail.missouri.edu*

Investigating the potential for testosterone to mediate territorial aggression in female Anolis lizards

Intrasexual aggression is an important component of animal social behavior. In the context of territoriality, such aggression may determine whether an individual is able to establish and maintain a territory. Thus, variation in territorial aggression has important implications for individual fitness. In males of many territorial species, such variation has been associated with intraspecific variation in circulating concentrations of hormones such as testosterone. Although females of many species also exhibit territorial aggression, it remains unclear for a variety of territorial taxa whether similar endocrine mechanisms regulate aggressive behavior in both sexes. Here, we investigated the potential for testosterone to mediate territorial aggression in female *Anolis gundlachi* lizards in Puerto Rico. In several *Anolis* species, males that engage in territorial interactions exhibit higher testosterone concentrations relative to less aggressive males. To assess whether a similar pattern occurs in females, we staged territorial interactions with free-living females and collected plasma to measure circulating testosterone concentrations. Preliminary results demonstrate that females exhibit aggressive behavior comparable to what is observed among males, and that aggression can vary considerably among females. Although testosterone concentrations seemed to vary more among females from the staged interactions relative to females from the general population, testosterone concentrations did not vary significantly between the groups. These results suggest that testosterone may influence aggressive behavior differently in males and females.

99-6 COOK, GM*; GRUEN, AE; MORRIS, J; PANKEY, MS; SENATORE, A; KATZ, PS; WATSON, WH; NEWCOMB, JM; New England College, Henniker, NH, University of New Hampshire, Durham, University of Toronto, Mississauga, ON, University of Massachusetts, Amherst; *gcook@nec.edu*

Circadian Clock Proteins in the Nudibranch Mollusks Hermissenda crassicornis, Melibe leonina, and Tritonia diomedea.

While many studies have reported on the molecular clocks underlying circadian rhythms in vertebrates and ecdysozoan invertebrates, such as arthropods, much less is known about these clocks in lophotrocozoan invertebrates. The goal of this project was to identify the RNA and protein products of putative clock genes in the central nervous system of three nudibranchs, *Hermissenda crassicornis*, *Melibe leonina*, and *Tritonia diomedea*. Using transcriptomics, we identified orthologs in each species for the products of five canonical clock genes: *bmal1*, *clock*, *non-photoreceptive cryptochrome*, *period*, and *timeless*. Orthologous sequences for the products of four related genes—*photoreceptive cryptochrome*, *cryptochrome DASH*, *6-4 photolyase*, and *timeout*—were also recovered. All of the resulting nudibranch proteins contained conserved functional domains found in their orthologs in other species. Phylogenetic analyses indicated that the nudibranch proteins were most closely related to the limited examples in other lophotrochozoan groups. A clock-related gene repertoire in the nudibranchs that includes both *timeless* and *timeout*, as well as both *photoreceptive* and *non-photoreceptive cryptochromes*, resembles what is seen in non-drosopholid insects and oysters, and may represent the ancestral circadian clock for bilaterians.

P3-160 COOPER, AN*; MORRIS, JS; CUNNINGHAM, CB; POTTS, WK; CARRIER, DR; University of Utah, Wofford College, Swansea University; *amanda.cooper@utah.edu*

Social Dominance in Male House Mice (Mus musculus): Muscle and Bone Mass Distribution

Intense physical competition between males for access to mating opportunities is widespread among mammals. In such agonistic encounters, dominant males often have greater reproductive fitness. However, the specific physical traits that facilitate social dominance are poorly understood. Body size is often correlated with reproductive fitness in mammals. Interestingly, body mass only weakly predicts fitness in male house mice (*Mus musculus*). We hypothesized that the distribution of both muscle and bone mass influences dominance status. We tested whether muscle mass differed when corrected for body size in dominant versus non-dominant males in two different competition experiments. In both studies, male mice competed in semi-natural environments for access to females residing in optimal territories: these competition experiments differed in their duration (3 days vs. 8 weeks), habitat size (0.42 vs. 30 m^2), male-to-female sex ratio (4:1 vs. 5:8), and number of rounds (2 bouts producing two-time winners and two-time losers vs. a single round of competition). The total mass of the dissected muscle groups was greater in dominant males in only one of the two experiments. Using the combined data, we discovered that dominant mice have greater mass in the muscles of the upper forelimb (biceps and triceps) and the gluteus muscles than their non-dominant counterparts. Muscle mass did not differ significantly in the hamstrings, knee extensors, or ankle plantarflexors. Bone mass measurements from one set of mice partially corroborate these results, with dominant mice possessing more massive forelimb bones. These results are consistent with our current understanding of house mouse agonistic behavior, which involves grappling with the forelimbs, often while standing bipedally.

29-4 COPPENRATH, CM*; LASALA, JA; GINGRAS, M; BALDWIN, J; Florida Atlantic University; *ccoppenrath2014@fau.edu*

Foraging Ecology of Florida's Nesting Leatherback Turtles: Insight from Stable Isotope Analysis

While many leatherback turtle (*Dermochelys coriacea*) nesting populations worldwide are decreasing, the North Atlantic population is considered Least Concern by the International Union for the Conservation of Nature. Florida's beaches, in particular, have experienced increased nesting numbers (10-11% per year on average) since organized nesting surveys began in 1979. With these increasing numbers, it is important to know which geographic areas are providing the energy sources necessary for vitellogenesis, migration, and nesting. While the migratory behavior of North Atlantic leatherback females has been documented in the Wider Caribbean, the migratory movements of South Florida's nesters are relatively understudied. Our knowledge of their migrations is currently limited to ten nesting females tracked from the east coast of Florida that either moved north to the North Atlantic or east to the coast of Western Africa, which brings to light the need for larger sample sizes in order to make population scale conclusions about the relative importance of different foraging areas for the South Florida leatherbacks. Here, we analyzed $\delta^{13}C$ and $\delta^{15}N$ signatures in whole blood and skin samples from leatherbacks nesting in South Florida between 2014 and 2017 to estimate where these nesters had been foraging prior to migrating to South Florida to nest. Additionally, we encountered remigrant turtles and were able to assess whether their foraging sites had changed from previous years. Forage quantity and quality can impact on the number of individual females that are able to nest in subsequent seasons. Florida's leatherback turtles appear to seek food over a broad geographic region, which may provide them with a degree of flexibility when some foraging areas are more favorable than others.

103-4 CORBET, M; JOYCE, C; SUR, A; RENFRO, A; MEYER, NP*; Clark University; *nmeyer@clarku.edu*

Function of BMP signaling in the annelid Capitella teleta and implication for nervous system evolution

A key question concerning animal evolution is how centralized nervous systems (CNSs) evolved and contributed to organismal diversity. In many animals with a CNS, a region of ectoderm receives extrinsic signals instructing it to become neural during the process of dorsal-ventral (D-V) axis specification. In vertebrates and insects, both processes rely in part on inhibition of BMP signaling by secreted antagonists, leading some to infer that neural specification is homologous within Bilateria. However, the little data we have from spiralians suggest that BMPs may not have played an ancestral role in neural specification. We studied to what extent BMP signaling is involved in neural fate and D-V axis specification in the spiralian annelid *Capitella teleta*. We analyzed expression of BMP ligands and their antagonists and found localization to specific quadrants during cleavage stages and to specific tissues after gastrulation. We manipulated BMP signaling during early-cleavage and gastrulation stages by soaking in recombinant BMP4 protein or in the inhibitor dorsomorphin. BMP4 protein did not disrupt D-V axis formation or block ventral nerve cord formation. Instead, BMP4 dramatically affected brain formation, causing a third brain lobe and eye to form. Treatment with dorsomorphin, which should block signaling downstream of BMPs, did not disrupt D-V axis formation and instead resulted in a loss or decrease of tissue in the ventral nerve cord. These results suggest that BMP signaling does not limit the domain of neural ectoderm in *C. teleta* as it does in insects and vertebrates. Our results are in agreement with data from other spiralians, indicating that nervous system evolution may have been more complicated than a single centralization event at the base of Bilateria.

65-1 CORCORAN, A. J.*; HEDRICK, T. L.; Univ. North Carolina, Chapel Hill; *aaron.j.corcoran@gmail.com*

Scaling of Flocking Dynamics with Body Size in Shorebirds

Rules underlying the collective movements of animals have been described for an increasing number of taxa in recent years, including for some fish, insects and birds. Considerable variation in flock density and network structure has been observed in different species. Complicating the interpretation of this diversity of behavior is a lack of controlled, cross-species comparative data. We address this problem by comparing flock dynamics of three species of shorebirds (Family Scolopacidae) that cover a more than 10-fold range in body sizes and 6-fold range of wingspans (Western Sandpiper, 28.5 g, 0.12 m; Short-billed Dowitcher 105 g, 0.51 m; Marbled Godwit 370 g, 0.79 m). We recorded bird flocks in Humboldt county, California in the spring of 2017 using three cameras recording at 29.97 frames per second. Cameras were calibrated for three-dimensional reconstruction of animal flight trajectories and flocks were reconstructed using automated computer vision algorithms. A preliminary analysis of one flock from each species examined flock densities, as measured by distances between each bird and its nearest neighbor. Average nearest-neighbor distances were 0.78 ± 0.77 m (median ± inter-quartile range; N = 31) for Western Sandpipers, 1.20 $\pm$ 0.65 for Short-billed Dowitchers (N = 331) and 1.21 ± 0.73 m for Marbled Godwits (N = 381). This preliminary analysis shows surprisingly little variation in flock density across a gradient of body sizes. Further approaches will include examining the effects of flock size on density and comparing flocking behavior of mixed-species flocks. This will help us interpret the rules underlying flock structuring, and to what degree they are set by the animal's intrinsic sensory and biomechanical constraints, verses extrinsic factors such as flight speeds and maneuverability of neighboring animals.

129-4 CORDEIRO, M; EDSINGER, E*; Roger Williams University, Providence, RI , Marine Biological Laboratory, Woods Hole, MA; *eedsinger@mbl.edu*

Why are cephalopod eggs so big? Testing viscosity and the functional limits of swimming in pygmy squid hatchlings.

Cephalopod eggs are exceptionally large compared to other marine invertebrates. Larger eggs produce larger hatchlings that experience a higher Reynold's number environment, where fluid momentum and turbulent flow increasingly dominate over viscous forces. We hypothesize that larger cephalopod egg sizes evolved in response to functional constraints inherent to their muscular jet and fin propulsion systems when operating at low Reynold's numbers. To test the influence of viscosity on swimming at the size limit of cephalopods, the "world's smallest" swimming cephalopod, hatchlings of the pygmy squid *Idiosepius paradoxus*, were used. Polyvinylpyrrolidone (PVP) can increase seawater viscosity without adverse affects on animals. Using a PVP concentration series, we tested the effect of viscosity on swimming rates in pygmy squid hatchlings. Average velocities per viscosity were calculated by video analysis. We found swimming became increasingly inefficient with increasing viscosity, and jet propulsion broke at dynamic viscosities greater than 9 cP. Hatchling sizes in normal seawater were calculated for PVP-based viscosities and velocities, and egg sizes were extrapolated. Our results indicate that at egg sizes typical in non-cephalopod molluscs, a cephalopod hatchling would swim poorly or not at all in normal seawater. Thus, the evolution of exceptionally large eggs in cephalopods may reflect a functional constraint of their muscular jet propulsion system when operating at low Reynold's numbers. Future studies may include testing the functional limits of jet and fin propulsion in other species, PIV characterization of swimming at increasing viscosities, and analysis of neural activity during swimming.

127-5 CORNWELL, BH; Univ. of California, Davis; *bhcornwell@ucdavis.edu*

Exploring the role of geographic isolation, host species, and selection in shaping the genetic structure of Symbiodinium sp. along the Pacific coast of North America

Host-symbiont interactions often form the foundation for ecosystem function and diversity around the world. One especially important relationship is the cnidarian-dinoflagellate endosymbiosis that exhibits exceptional flexibility, forming coral reefs while also extending into temperate latitudes. This diversity also extends to the molecular level, where genotyping techniques have revealed that the dinoflagellate symbionts *Symbiodinium* sp. can be classified into 9 major clades using the molecular marker ITS2. However, much less is known about within-clade variation, which ITS2 largely fails to resolve. Genetic loci that provide more resolution (microsatellites) produce patterns suggesting that within-clade symbiont populations can specialize on different environmental conditions, geographic locations, and host species. It is now possible to survey loci across the entire genome to determine the relative impact of these forces on *Symbiodinium* populations. Here, I use a genome-wide SNP dataset to explore the genetic structure of *Symbiodinium* sp. (all from Clade B) populations that form partnerships with three sympatric species of anemone in the genus *Anthopleura* along the Pacific coast of North America. First, I show that symbiont populations separated by hundreds of km are highly genetically differentiated, and within each locality, symbionts are further genetically differentiated by host species. Second, I identify signatures of adaptation in symbiont subpopulations that correlate with abiotic conditions across several degrees of latitude, a crucial step in determining the contributions of both hosts and symbionts to the performance of the holobiont across temporally and spatially heterogeneous environments.

P1-20 COST, IN*; MIDDLETON, KM; HOLLIDAY, CM; Univ. of Missouri, Columbia; *incqm2@mail.missouri.edu*

Mechanical Performance in the Skulls of Parrots (Aves: Psittaciformes)

Movement among intracranial joints, cranial kinesis, is a fundamental function of the feeding apparatus of parrots. The skulls of parrots possess a mobile quadrate which drives movement of the mandible, palate, and rostrum. These kinetic movements are facilitated by a mixture of joint tissues at the otic, palatobasal, palatomaxillary, and craniofacial joints of the skull. Because of the anatomical similarity of the feeding apparatus, the soft and bony tissues of the linkage system are hypothesized to mitigate stresses and strains associated with feeding in similar patterns across parrots despite disparate dietary niches. Here we test this hypothesis in taxa exhibiting diverse dietary regimens by mapping stress and strain propagations within the skull and across joints. Using the BoneLoad workflow, jaw muscle forces were estimated using volumetric properties and bite forces estimated using 3D lever mechanics. Finite element models were loaded using flexible joints with anatomically accurate sutural material properties and anatomically informed constraints. Estimated bite forces were then applied to homologous points of the maxilla across all four taxa to generate a simulated load on the feeding apparatus. Resulting mechanical properties were qualitatively analyzed across the skull. Regions of interest were sampled in the pterygoid, palatine, and quadrate bones to quantitatively compare models. Our results indicate that feeding-generated forces and strains about kinetic joints are similar among the sampled parrots. This suggests dietary preferences of parrots may be better reflected by their feeding behaviors and other features such as beak shape, or tongues. Regardless, the kinetic linkage remains an innovation underlying parrot feeding behavior and new details will improve future ecomorphological and evolutionary hypotheses in extant and extinct kinetic birds and archosaurs.

141-7 COSTA, D. P.*; HUCKSTADT, L. A.; VILLEGAS-AMTMANN, S.; Univ. of California, Santa Cruz; *costa@ucsc.edu*

The Importance of Body Size in Diving Mammals: Small Marine Mammals Compensate

The aerobic dive limit (ADL) an important determinant of diving ability scales with body size. As metabolism scales with mass^0.75 and oxygen stores scale with mass^1.0, larger animals should have a greater diving ability than smaller mammals. We compared the ADL of pinnipeds with respect to their foraging behavior to determine when body size is important and when other physiological adjustments come into play. We compared the physiological determinants of ADL in all 6 extant species of sea lions. ADL was estimated from measurements of total body oxygen stores (muscle, blood and lung) and estimates and or measures of metabolic rate. If diving ability were the primary factor driving body size, we would predict that larger sea lions should dive longer and deeper than smaller sea lions, who should dive shorter and shallower. However, we found the opposite pattern the smallest sea lion, the Galapagos sea lion, had the longest average dive duration and was the second deepest diver, while the two largest sea lions, the Steller and southern sea lion, exhibited the shallowest and shortest dives. The oxygen stores of the longest divers had the greatest oxygen stores and in some cases lower metabolism. This suggests that differences in body size are more related to ecological factors (prey availability and abundance) than diving ability. We also observed that the physiological capacity (oxygen stores) tracked the seasonal changes in dive behavior. California sea lions that made shallower shorter dives in the winter had lower O2 stores than sea lions who made deeper longer dives during the summer, implying that sea lions are able to increase their diving capacity through "conditioning".

16-5 COSTA, D. P.*; HUCKSTADT, L. A.; SCHWARZ, L.; FRIEDLAENDER, A.; MATE, B.; ZERBINI, A.; KENNEDY, A; GALES, N. J.; Univ. of California, Santa Cruz, Oregon State University, National Marine Fisheries Service, Australian Antarctic Division; *costa@ucsc.edu*

Assessing the Potential Exposure of Migratory Animals to Disturbance

While many studies have examined the sensitivity of marine animals to underwater noise an essential component of any risk assessment is the likelihood that individuals of a given population will be exposed to that disturbance. An essential component of risk assessment is identification whether individuals will be exposed to a risk. This requires information on the proportion of the population exposed, for how long, and during what activity (i.e., feeding, migrating, and breeding). Using satellite telemetry data for humpback and blue whales feeding and migratory regions in Antarctica, California, and Bering Sea, we modelled the potential exposure of individuals to an acoustic disturbance. Foraging and transit regions along the tracks were identified and using a switching state space model the time spent foraging in each region calculated. A simulated seismic survey was randomly placed (100 iterations) within the habitat of each of species and the amount of time individual animals were exposed determined. A large disturbance (i.e. 100 km) only exposed 6% of the population of humpback whales in Antarctica and 19% blue whales off California. In contrast, humpback whales in the Bering Sea experienced high exposure with only a 5 km disturbance. This approach can be used to develop a framework for estimating the likelihood that a given animal population would be exposed to disturbance and to develop general risk assessment guidelines. Output from this exposure model can be used to evaluate the potential effect of disturbance on an animals energy budget in terms of energy expended but not acquired and how that would effect on offspring growth and survival.

20-4 COSTA-PAIVA, EM; SCHRAGO, CG; HALANYCH, KM*; Universidade Federal do Rio de Janeiro, Auburn University; *ken@auburn.edu*

Diversity of Hemerythrin and Hemocyanin Blood Pigments across Metazoa.

Four families of oxygen-binding proteins are found in animals, which are divided into two major groups: proteins that use iron to bind oxygen (hemoglobins and hemerythrins) and two non-homologous families of hemocyanins that use copper. Hemerythrins (Hr) genes are present in the three domains of life, Archaea, Bacteria, and Eukaryota; however, within Animalia, Hrs have been reported only in marine species in six phyla (Annelida, Brachiopoda, Priapulida, Bryozoa, Cnidaria, and Arthropoda). Hemocyanins, found in arthropods and molluscs, bind oxygen in the same manner, but they are distinct in their molecular structure - often designated HcA and HcM, respectively. We investigated the diversity and evolution of Hr, HcA and HcM in metazoans, by employing in silico approaches to survey >100 metazoan transcriptomes and genomes. We found 58 candidate Hr genes actively transcribed in 36 species distributed in 11 animal phyla, with new records in Echinodermata, Hemichordata, Mollusca, Nemertea, Phoronida, and Platyhelminthes. Moreover, we found that "Hrs" reported from Cnidaria and Arthropoda were not consistent with that of other metazoan. Five putative novel HcM genes were retained from taxa examined in this study, including two annelid species from the same family, Chaetopteridae. Concerning HcA, 18 putative novel genes presenting at least two of the three domains were retained, representing 18 metazoan species distributed across six phyla. The presence of HcA in Annelida, Cycliophora, and Echinodermata represent novel observations. Work presented here contradicts the canonical view that 1) Hemerythrins are absent in deuterostomes and 2) hemocyanins are restricted to molluscs and arthropods. The occurrence of blood pigments in metazoans is underestimated.

P3-51 COUGHLIN, DJ; Widener University, Chester, PA; *djcoughlin@widener.edu*

Analysis of Gene Expression in Rainbow Smelt: Assembly of a Non-Model Organism Transcriptome Using Trinity

Rainbow smelt, *Osmerus mordax*, have an impressive ability to acclimate to very cold water. Smelt exposed to cold for an extended period of time have faster sustained swimming speeds and increased contraction kinetics in their myotomal muscle compared to warm acclimated fish. We used RNA-Seq to explore how gene expression underlies thermal acclimation in these fish. Transcriptome analysis is limited in species that lack an annotated genome, such as rainbow smelt. The *Trinity* software package (Broad Institute) permits the de novo assembly of a smelt transcriptome with a modest learning curve. The workflow was extended with *Kallisto* to quantify the abundance of each transcript represented in the full transcriptome and *Sleuth* to analyze the resulting RNA-seq datasets. Subsequently qPCR can be used to confirm patterns of thermal acclimation and gene expression for gene of metabolic and muscle contractile function. This approach has proven fruitful in revealing the genes responsible for the increase in physiological performance in over-wintering smelt.

S5-10 COX, SM*; GILLIS, GB; The Pennsylvania State University, Mount Holyoke College; *smc288@psu.edu*

Preparing for Impact: Sensory Feedback and Controlled Landing in Hopping Toads

A controlled landing requires preparation. In midair, cane toads (*Bufo marinus*) activate muscles to initiate movements that position their forelimbs appropriately at the point of impact to absorb and dissipate energy during landing. These preparatory actions vary depending on the hop conditions. For example, longer hops lead to a more extended forelimb configuration at impact, and hops in which an animal rolls to one side after takeoff lead to asymmetrical patterns of forelimb movement and muscle activity. The ability of anurans to vary landing preparation with impact conditions appears to require the integration of sensory feedback, yet little is known about the necessity or prioritization of various sensory modalities for coordinated landing in hopping anurans. Here we present several experiments in which feedback from visual, vestibular and proprioceptive systems were conflicted or ablated. We found that landing preparation was altered if any sensory system was compromised. In visually impaired animals, subtle changes in the timing and magnitude of forelimb preparatory movements were observed, and the same was true of animals lacking hind limb proprioceptive feedback during takeoff. Nevertheless, in both conditions the ability to coordinate landing was preserved. In contrast, landing coordination was totally disrupted by the absence of vestibular information as a result of unusual takeoff angles and abnormal forelimb and hind limb movements following takeoff. Our most intriguing results from experiments conflicting sensory signals showed that toads appear to prioritize different modes of sensory feedback depending on hopping conditions and that, unlike mammals, cane toads may rely most heavily on non-visual feedback to coordinate landing.

80-3 COX, C. L.*; DAVIS RABOSKY, A. R.; CURLIS, J. D.; WATSON, C. M.; Georgia Southern University, University of Michigan, Midwestern State University; *clcox@georgiasouthern.edu*

Convergent evolution of startle coloration in snakes

Predator-based selection is considered a major driver of phenotypic diversity, from the dynamics of mimicry systems to the extraordinary patterns of crypsis and background matching. Research focused on aposematism and mimicry has revealed that antipredator coloration has multiple independent origins and is characterized by substantial rate heterogeneity. Both mimetic and aposematic coloration are warning signals (sometimes dishonest) for antipredator defenses, but simple contrasting coloration can also effectively startle or confuse a predator. Importantly, differences in costs to the predator and prey between warning signals (mimicry and aposematism) and defensive coloration (startle and decoy coloration) have the potential for alternative macroevolutionary consequences. We studied the evolution of startle coloration in snakes, which often have brightly colored ventral surfaces (red to yellowish-orange) that are displayed to predators during an attack. Using a combination of phylogenetic comparative methods, large phylogenies, and a dataset of ventral color for over 800 species, we found that there have been multiple independent origins of the brightly colored venter, with most extant occurrences of this trait reflecting independent origins. Contrastingly, there have been very few losses, and most of the origins were relatively recent (last 10 million years). Our results suggest differing dynamics for the evolution of startle coloration compared to aposematism and mimicry, implying that the evolution of traits driven by the same predator-based selection pressure may have alternate macroevolutionary outcomes.

65-6 CRALL, JD*; DE BIVORT, BL; Harvard University; *jcrall@oeb.harvard.edu*

Circadian Behavioral Dynamics in Bumblebee Colonies are Disrupted by a Neonicotinoid Pesticide

Social insects are capable of collectively responding to environmental perturbations in the absence of central control. A key challenge for studying the health of social insects such as bees and the ecosystem services they provide is understanding how proximate effects of environmental stressors on individual workers impact these collective behaviors. Here, we study the temporal dynamics of worker behavior and their disruption by a common neonicotinoid pesticide in bumblebee (*Bombus impatiens*) colonies. Using an automated system to continuously monitor behavior of individual workers from multiple colonies in parallel, we show that (a) worker behavior shows strong and stable circadian dynamics within bumblebee colonies, and that (b) exposure to field-realistic concentrations of imidacloprid (~6 ng/g) disrupts key aspects of worker behavior (including nursing), but that the impacts are variable over the circadian cycle, with the strongest effects occurring at night. We find a similar pattern for collective thermoregulation performance in colonies exposed to imidacloprid in the field. Finally, using a combination of modeling approaches and automatic thermal tracking of individual workers, we examine the role of socially-modulated arousal in driving these colony-level behavioral dynamics. Overall, our results show that neonicotinoid pesticides impact worker behavior and colony performance through complex interactions with the environment, and highlight the need for a more complete understanding of the physiological and neurobiological underpinnings of collective behavior in bumblebees.

P2-66 CRAVENS, Z. C.*; BOYLES, J. G.; Dept. of Zoology, Southern Illinois Univ., Carbondale; *zcravens@siu.edu*

Shedding Light on Refueling Rates in an Insectivorous Bat Community

Global light pollution is increasing worldwide, nearly doubling over the past 25 years. The encroachment of artificial light into remaining dark areas threatens to disturb natural rhythms of wildlife species. Artificial light impacts the behavior of insectivorous bats in numerous ways, including changing foraging behavior and altering prey selection. It is often suggested that bats should forage more commonly on moths, or on larger moths, relative to other available prey around artificial light, likely due to a higher energetic payoff. In a manipulative field experiment, we measured plasma &beta-hydroxybutyrate concentrations from 4 species of insectivorous bats in naturally dark and artificially lit conditions to investigate effects of light pollution on fueling rates (a proxy of foraging success). &beta-hydroxybutyrate increases predictably in both captive and free-living bats after feeding and can thus be used to measure foraging intensity. Contrary to predictions, fueling rates did differ consistently between experimental conditions for any species. In general, fueling rates at lit sites were highest early in the night followed by a decrease, while the opposite was the case at unlit sites. Our results, building on others, demonstrate that bat-insect interactions may be more nuanced than the common assertion that moth consumption increases around lights. Our work highlights the need for greater mechanistic understanding of bat-light interactions to predict which species will be most affected by light pollution, and to more effectively craft management strategies to minimize unnatural shifts in prey selection caused by artificial lights.

P1-21 CRAWFORD, CH*; RANDALL, ZS; FLAMMANG, BE; New Jersey Institute of Technology, Florida Museum of Natural History; *crawford.callie@gmail.com*

Variation in Pelvic Morphology of Balitorid Fishes

Balitoridae, the hillstream loaches, is a family of cypriniform fishes living in high-flow streams and rivers of South and Southeast Asia. The family currently consists of 18 recognized genera including a monotypic blind cave genus, *Cryptotora*. In previous work we found that the cave loach, *Cryptotora thamicola* (previously *Homaloptera*), was able to walk out of water with a tetrapod walking gait as a result of having a robust pelvic morphology that is rigidly attached to the vertebral column, similar to tetrapods. We have since examined the pelvic morphology of 20 balitorid species and found that there are three general pelvic morphs that represent a spectrum of pelvic girdle robustness and attachment to the vertebral column. Further work will use kinematics and electromyography to compare the weight-bearing walking capabilities of these three different pelvic morphs. The expected outcome is that the more complete connection between the vertebral column and the pelvis, e.g. more similar to the morphology observed in *C. thamicola*, will allow for an increased ability to bear weight and thus increased capacity for walking.

P1-290 CRAWFORD, R.M.*; FINNEGAN, D; KOLMANN, M.A.; BUSER, T; WELLS, C.D.; University of Washington, Oregon State University; *racheb6@uw.edu*

Functional Morphology and Feeding Ecology of the Anemone-Eating Mosshead Sculpin Clinocottus (Blennicottus) globiceps

The intertidal zone is characterized by high energy and tidal exchange, resulting in a highly dynamic environment with frequent aquatic-air transitions. This dynamic ecosystem may be responsible for the evolution of specialized morphological and physiological adaptations to help organisms survive in this environment. One unusual intertidal adaption is found in an exposed intertidal sculpin, *Clinocottus (Blennicottus) globiceps*, which feeds on anemones. Anemones have barbed nematocysts that make them a hazardous food source not consumed by many organisms, including the other *Clinocottus* species. Do specialized morphologies or behaviors facilitate anemone-feeding in *C. globiceps*? We predicted that the blunt, rounded head and specialized dentition of *C. (B.) globiceps* allow it to effectively feed on anemones while protecting the fish from the stinging tentacles. We used high-speed video to analyze the feeding behavior of *Clinocottus globiceps*. We also used micro-computed tomography scanning coupled with iodine contrast-staining, as well as scanning electron microscopy of the jaws to resolve a feeding morphospace for the *Blennicottus* subgenus, and compare *C. globiceps* to its immediate relatives. We found that skeletal morphology does differ across species in the *Blennicottus* subgenus, and that *C. (B.) globiceps* is a morphological outlier. However, little is known about the factors that cause this differentiation. We found that full body-shaking movement (similar to an alligator's ‘death-roll') exhibited by *C. (B.) globiceps*, as well as teeth shaped for tearing, play the largest role in *C. (B.) globiceps* ability to feed on anemones effectively.

P1-126 CRAWFORD, AR; SO, C; SHARMA, PP*; University of Wisconsin-Madison; *prashant.sharma@wisc.edu*

Embryonic Development and Staging of the Harvestman Phalangium opilio

Opiliones, also known as "harvestmen" or "daddy longlegs", is an arachnid order with an ancient fossil record and considerable extant diversity. The prolific and synanthropic species *Phalangium opilio* is easily accessible in many parts of the world, as well as in a laboratory setting. Resources for this species include a developmental transcriptome and protocols for RNA interference, but the embryogenesis of this species has not been well characterized. We present a staging system of *P. opilio* embryogenesis using different morphological landmarks to delimit key events during the development of this harvestman. Using confocal microscopy, we tracked the development of a single synchronous clutch of eggs from egg laying through adulthood. This staging system provides a valuable reference for *P. opilio* that we anticipate to be useful to the arachnid evo-devo community.

P2-189 CROFTS, SB*; CRAWFORD, C; BONNAN, M; FLAMMANG, BE; UIUC, NJIT, University of Stockton; *tatterdemalion7@gmail.com*

Skeletal morphology of swimming lizard tails

The genus *Varanus* encompasses a diverse and speciose group of reptiles, which occupy a broad range of ecological niches, and are endemic to three continents (Africa, Asia, and Australia). Phylogenetic analyses show a number of independently derived semi-aquatic lineages, with closely related terrestrial and/or arboreal species, exhibiting a strong relationship between body shape and ecology. The goal of this project is to compare tail skeletal morphology between terrestrial and semi-aquatic species, and identify any convergent trends. Varanids are an especially appropriate model system for studying the transition from terrestrial to marine environments due to their hypothesized close relationship to mosasaurs; however, this relationship has recently been called into question. Previous work focusing on vertebrae from the neck to the pelvic girdle has demonstrated measurable differences in in zygapophyses, articular surfaces, and centrum lengths, all of which are likely related to forces generated during swimming. Reptiles that swim via undulation increase their propulsive surface by having dorsoventrally expanded, laterally compressed tails. The difference in muscle force needed for swimming versus non swimming locomotion, as well as the change in overall tail shape, may also be reflected in the morphology of the caudal vertebrae. Using CT data, we have reconstructed tail vertebrae from 15 species of varanids and from Green Iguana and Marine Iguana specimens, and have measured and compared neural spine, transverse process, and centrum morphology.

P3-175 CROGHAN, J/A*; ROOSENBURG, W/M; WILLIAMS, S/H; Ohio University; *jasmine.croghan@gmail.com*

Inter- Versus Intraspecific Variation in Testudine Crania Using a Population of Diamondback Terrapins (Malaclemys terrapin)

The presence of intraspecific variation in skeletal morphology is problematic for morphological analyses with low sample sizes. To assess the validity of utilizing low sample sizes within species in interspecific morphological analyses, we analyzed the size of the morphospace occupied by a sample of Diamondback Terrapin (*Malaclemys terrapin*) crania versus that occupied by a broad sample of extant testudine species. Ten Male and 10 female *M. terrapin* specimens and 22 testudine species representing extant diversity were CT-scanned and subsequently reconstructed as 3D digital models. These models were landmarked with the R-package auto3DGM. The generated pseudolandmarks were then subjected to a Generalized Procrustes Alignment and further analyzed within the R-package geomorph. The Procrustes-fit points were used in a disparity analysis which compared the morphospace sizes of groups of specimens. We hypothesized that interspecific disparity values would be much greater than intraspecific disparity values. The disparity within the interspecific sample was 0.043 while the disparity within the intraspecific sample was 0.016. The nearly three-fold increase in interspecific disparity suggests that the overall pattern of testudine species in morphospace is unlikely to be affected by the small changes in position that individuals within a species may cause. Indeed, a Principal Components Analysis of these points reveals a tightly clustered intraspecific sample along all PC axes. Notably, although *Malaclemys terrapin* is quite sexually dimorphic among testudines, this did not greatly affect the position of the species relative to others in tangent space. Nevertheless, caution is warranted when sampling species that have demonstrated extreme sexual dimorphism.

42-5 CROVO, JA*; JOHNSTON, CE; Auburn University, Auburn University ; *jac0058@auburn.edu*

Dude Looks Like a Lady: Evidence of Sneaker Males in a Cyprinid Fish Species

Fishes utilize a variety of reproductive strategies during spawning. Satellite, or sneaker, males are non-territorial individuals that mimic females to gain access to unfertilized eggs. Sneaker males have been documented in a variety of fishes; however, this is the first observation of this strategy in cyprinid fishes. Using the soniferous blacktail shiner (*Cyprinella venusta*) as a model, we conducted a series of conspecific acoustic playbacks to dominant and sneaker males to measure changes in 11-ketotestosterone (11KT). GSI indices were also calculated for dominant and sneaker males. Sneaker males had considerably larger testes relative to body size compared to territorial males. In territorial males, 11KT production was size dependent; larger males released significantly more 11KT in response to conspecific playback. Smaller territorial males released significantly less 11KT when exposed to the same acoustic signal. Sneaker males exhibited an 11KT spike in response to courtship acoustic signals; thus, this signal could act as an acoustic spawning cue. Future work aims to discover if this relationship is genetically-based or context dependent.

P2-53 CRUZ, P*; BLACK, T; FOFAH, O; ORTIZ, C; BARTHELL, J; AGOSTO, J; GIRAY, T; ABRAMSON, C; Univ Puerto Rico Rio Piedras, Oklahoma State Univ, Oklahoma State Univ , Univ of Puerto Rico Rio Piedras, Univ Central Oklahoma ; *paula.cruz5@upr.edu*

The Effect of Uncontrollable Stress on Plasticity and Stress Related Gene Expression in the Honey bee, Apis mellifera

Although the effect of stress on learning has been studied, we have limited information about how learning can induce physiological stress. We used the honeybee Apis mellifera to study the relationship between learning and stress given the learning protocols and behavioral/genetic analyses used in honeybee research. We used the Shuttle box protocol designed by Dinges et al. (2017) to simulate controllable (CS) and uncontrollable (US) stress. Animals assigned to the master condition (CS) had control as to when they were shocked while honeybees assigned to the yolk condition (US) had no control. After the behavioral phase, we dissected the honeybees' brains, extracted RNA, and carried out RT-PCR to quantify the expression of the following genes: DH44, DLG, 5HT2A, DAR2, CAMK, HsP70, BRP, PKA, PUM and DH44R. ANOVA revealed a significant increase in the expression of the plasticity gene DAR2 in animals exposed to US and no statistically significant differences in other measures. However, we observed a tendency (increased gene expression) in DH44 and its receptor and in receptors 5HT2A and DAR2 in animals assigned to US. Post hoc power analysis revealed that sample sizes were too small to reach required statistical power. Our data suggest that honeybees are suitable for studying the biobehavioral mechanisms underlying the effect of learning on stress. Dopamine signaling via DAR2 might play a role in the neural adaptations associated with uncontrollable stress. For future research, we recommend analyzing gene expression in specific brain regions and extracting and dissecting the brain at different times of the day to study the interaction between gene expression and circadian rhythms.

139-8 CUFF, AR*; OTERO, A; ALLEN, VA; MICHEL, KB; SUMNER-ROONEY, L; POL, D; HUTCHINSON, JR; Royal Veterinary College, UK, Museo de La Plata, Argentina, Oxford University Museum of Natural History, UK, Museo Paleontológico Egidio Feruglio, Argentina; *acuff@rvc.ac.uk*

Ontogenetic changes in the body plan of the sauropodomorph Mussaurus and their implications for locomotion

Mussaurus patagonicus is a sauropodomorph from the Early Jurassic of Argentina, originally described from hatchling remains. Further discoveries of juvenile and mature specimens provide a sufficiently complete series to reconstruct general patterns of ontogeny. Here, one each of hatchling, juvenile (~1 year old), and adult (8+ years old) individuals was studied. Digital models of the bones were created for each specimen, from segmented µ-CT scans for the smaller bones and photogrammetry and laser scans for the larger bones. Modelled bones were then articulated to produce complete skeletons, with missing bones being replaced by scaled versions of adults or closely related taxa. Each skeleton was wrapped in convex hulls and more anatomically realistic shapes, which were used to estimate body mass and centre of mass, and to conduct sensitivity analyses of these calculations. Our results show that *Mussaurus* rapidly grew from about 50g at hatching, to ~7kg at one year old, and reaching ~1540kg at adulthood. During this time the body's centre of mass moved from a position in the mid-thorax to a more caudal position nearer the pelvis, consistent with a shift from quadrupedalism to bipedalism that might have occurred early in ontogeny in *Mussaurus* and other early sauropodomorphs. Our findings offer important new insights into the evolution of locomotion across Sauropodomorpha; consistent with a heterochronic shift to quadrupedalism near Sauropoda.

P1-212 CULLER, MC*; EVANS, LA; JACOBS, KP; ONTHANK, KL; Walla Walla University, Washington State University; *monica.culler@wallawalla.edu*

Octopuses in a Changing Environment: How Increasing Temperature and Ocean Acidification Affect the Metabolic Physiology of Octopus rubescens

Global climate change, caused primarily by a substantial increase in the burning of fossil fuels since the Industrial Revolution, has strong impacts on marine ecosystems. Ocean acidification and warming sea surface temperatures are the results of the oceans absorbing the excess carbon dioxide and heat from the atmosphere. These changes in water conditions may have a variety of detrimental impacts on marine organisms. Cephalopods may be particularly sensitive to changes in environmental pH due to their use of hemocyanin as an oxygen transport pigment, which has strong Bohr and Root effects. Thus, the affinity and carrying capacity of hemocyanin for O_2 is decreased in a low pH environment. In addition, sensitivity to pH is increased in warmer temperatures. We constructed energy budgets for *Octopus rubescens* exposed to high pCO_2 and high temperature treatments, both separately and combined. Energy budgets were calculated based on metabolic rates, consumption, and growth. We also measured the critical oxygen pressures of each octopus after five weeks of treatment because of the possibility of reduced oxygen transport in these conditions. Our results suggest that energy budgeting is altered in response to expected climate change conditions, with significantly more energy allotted to growth and metabolism than when in control or single treatment conditions. Additionally, the critical oxygen pressure is significantly increased when exposed to the combined higher pCO_2 and temperature, suggesting that *O. rubescens* may have a reduced habitat range due to decreased hypoxia tolerance.

P2-53.1 CUMMINGS, CR*; KAHN, NY; MURRAY, M; ELLISON, TJ; WELCH, CN; HERNANDEZ, SM; NAVARA, KJ; University of Georgia; *cummings.carolineruth@gmail.com*

The Effects of Urbanization on Stress and Immunity in White Ibis (Eudocimus albus)

Changes in land-use due to rising human populations are affecting wildlife as natural habitats become more urbanized or are degraded. The ability of a species to adapt to urban environments and the associated novelty is important when considering conservation of species for when suitable habitat has disappeared. Exposure to urban environments can have dramatic impacts on the health and physiology of wildlife, however many species are still abundant in these environments, including white ibis (*Eudocimus albus*). While they originate in and breed in remote wetland habitats, some populations of white ibis can be found foraging in urban parks throughout Palm Beach County, FL. Further, their diet has shifted from protein-rich crustaceans and insects to carbohydrate-dense "junk" food, either as a result of anthropogenic feeding or foraging in human-generated landfills. The impacts of the shift away from their natural habitat and diet on their physiology, behavior, and vectors of zoonotic disease is vital to their conservation and management. We hypothesized that "urban" ibis would exhibit higher levels of stress and would show inhibited immunity. To determine this, we captured ibis from both "urban" and natural populations and tested for bacteriocidal capacity (via bacterial killings assays) and circulating corticosterone levels at various times of capture to measure acute and chronic stress levels. These parameters were then compared between the two populations of ibis. Contrary to our hypothesis, urban ibis are significantly better killers of *E. coli* and *Salmonella* than their natural wetland counterparts. The significance of these results and their relationship to plasma corticosterone will be discussed.

P3-99 CUNHA, AAP*; PARTRIDGE, CG; DIXON, B; KNAPP, R; NEFF, BD; University of Western Ontario, Ontario, Grand Valley State University, Michigan, University of Waterloo, Ontario, University of Oklahoma, Oklahoma; *acunha6@uwo.ca*

Effect of Prolactin and 11-ketotestosterone Manipulation on Parental Care Behavior and Immune Response in Male Bluegill Sunfish (Lepomis macrochirus)

Animals that provide parental care to their offspring often face behavioural and immunological trade-offs. Hormones have been implicated in mediating these trade-offs, with androgens often promoting aggressive behaviours at the expense of both reduced nurturing behaviour and immunity. Conversely, prolactin can promote nurturing behaviour and immunity but may reduce aggressive behaviours. We tested the effects of these hormones on parental care and immunity in bluegill sunfish, a species in which males build nests and provide sole parental care to the offspring. Immediately after spawning, parental males received one of five hormone manipulations: (1) placebo; (2) 11-ketotestosterone (11-KT); (3) flutamide, an androgen receptor antagonist; (4) prolactin; or (5) bromocriptine, a prolactin-release inhibitor. We then recorded the frequency of nurturing and aggressive parental care behaviours and measured their immune response to exposure to Vibrio. We found that prolactin-treated males exhibited significantly more nurturing behaviours, whereas 11-KT-treated males exhibited more aggressive behaviours relative to the other treatments. Within hormone treatments, there was no apparent effect of the immune challenge on these behaviours. We discuss the hormone-mediated trade-offs during parental care and the immune response in the parental males.

110-1 CUNNINGHAM, BE*; BREITENBACH, KK; ADAMS, NL; California Polytechnic State University, San Luis Obispo; *bcunni02@calpoly.edu*

The release of zinc oxide sunscreens into marine environments and their effects on developing Strongylocentrotus purpuratus embryos

Increased releases of zinc oxide (ZnO) sunscreen ingredients into marine environments will accompany the growing popularity of physical sunscreens. Though zinc (Zn) is a necessary micronutrient in the ocean, greater than natural amounts of Zn enter marine environments by anthropogenic sources. The consequences of adding Zn to the ocean are not fully understood. We tested how physical factors affect the release of non-nano Zn and other sunscreen ingredients into seawater and effects of these ingredients on the development of California purple sea urchin, *Strongylocentrotus purpuratus*, embryos. We hypothesized that despite being labeled "reef or environment safe", these sunscreens will have negative effects on the development of larval urchins because they release Zn^{2+}, which may be internalized by the developing embryos. By simulating human Zn release during swimming using sunscreen on pig skin, we saw changes in Zn^{2+} release accompanying changes in water temperature, submersion duration and due to different formulations. To test toxicity, we exposed embryos to varying levels of ZnO sunscreens during development and observed the morphologies at the pluteus stage. Early exposure to ZnO sunscreens cause abnormalities typical of those observed in embryos exposed to Zn^{2+} during development. Additionally, we used fluorescent probes to quantify the levels of Zn^{2+} internalized, the amount of reactive oxygen species (ROS) produced, and the functional ability of the multidrug resistant transporters within the treated embryos. The combination of these assays will contribute to our understanding of how increased levels of internalized Zn^{2+} released by sunscreens can affect marine organisms.

P3-82 CUPP, JR., P/V; Eastern Kentucky University; *paul.cupp@eku.edu*

Mate-Guarding and Pair-Bonding Behavior in Green Salamanders, Aneides aeneus

Male *Aneides aeneus* arrive at home crevices and establish territories through chemical deposits and often aggression with other males. Females usually follow soon after. Thus, male-female pairs are formed in single rock crevices or in adjacent crevices for periods of days or weeks mainly in May and October. Pair bonding occurs that likely involves chemical and tactile communication. Males and females may gain familiarity with each other. Male-female pairs are often in direct contact as males may have a limb or other body part resting on the back or tail of females. Also, heads of male and female may be oriented to opposite ends of crevice openings with posterior ends in contact. In two instances, a Y-shaped posture was observed with the heads of male and female separated and apparently on guard while the posteriors were in contact forming the lower part of the "Y". This may be a defensive response to predators. Pairing increases chances of courtship and mating, and allows for mate guarding thus reducing chances for polyandry and polygyny. Some aggression by males may occur such as biting and snout-pressing, which is similar to behaviors observed during courtship and mating. Males that have established and defended territories are likely more fit. Thus, mate-guarding behavior may be selected for in that females may choose more fit males. Aggressive defense of territories by males combined with the formation of male-female pairs and pair bonding indicates that mate guarding occurs in *A. aeneus*. This may enhance reproductive success of both males and females.

13-7 CURREA, JP*; THEOBALD, JC; Florida International University; *johnpaulcurrea@gmail.com*

Limited Larval Feeding Leads to Smaller and Slower Adult Eyes in the Fruit Fly

Wild adult fruit flies vary in size due to variable food availability during early development, but how this variation impacts their eye size, vision, and flight behavior remains largely unknown. For holometabolous insects like the fruit fly, growth is almost entirely restricted to the larval stages and lower larval feeding results in smaller adult flies. Smaller adult flies possess smaller eyes that, in principle, must sacrifice spatial acuity or contrast sensitivity due to smaller optics. Such small eyes are common in nature where larval nutrition is limited and ephemeral. However, because fruit fly vision is currently understood from uniformly large, lab-reared adults, how their visual development copes with small optics is unknown. Do smaller eyes sacrifice spatial acuity, by increasing their inter-ommatidial angle, or contrast sensitivity, by decreasing their ommatidial diameter? Further, might the visual system neurally adapt to these optical constraints via temporal or spatial pooling? To address these questions, we generate a broad distribution of eye sizes by removing larvae from their food during their third instar and measure the optical and functional effects of small eyes on their vision. Using a digital recording microscope, an immersive visual arena, and psychophysical paradigm, we show that small eyes maintain spatial acuity by sacrificing contrast sensitivity at the optical level, but recover contrast sensitivity by sacrificing temporal acuity at the neural level. Therefore, we find that smaller flies, due to limited larval feeding, have smaller and slower but otherwise normal eyes. [NIH/NIGMS grant R25 GM061347 to JPC]

P1-154 CURRIER, SL*; CAPELLE, PM; SEMENIUK, CAD; HEATH, DD; VINCELLI, FA; LOVE, OP; University of Windsor, Windsor Ontario, Great Lakes Institute for Environmental Research, Windsor Ontario, Great Lakes Institute for Environmental Research, Windsor Ontario, University of Windsor and Great Lakes Institute for Environmental Research, Windsor Ontario; *currier@uwindsor.ca*

Sex Specific Responses to Interactions Between Pre- and Postnatal Stress and Their Impact on Performance in Chinook Salmon (Oncorhynchus tshawytscha)

Exposure to prenatal stress affects an offspring's physiology, development and behavior. Although most research to date has branded short-term effects as negative impacts, recent work indicates that prenatal stress is a signal to match offspring to the quality of their future environment to maximize fitness. Although we expect males and females to differ in their phenotypic responses given sex-specific differences in proximate and ultimate costs, few studies have examined sex-specific effects of pre- and postnatal stress on offspring traits. We examine sex-specific effects of pre- and postnatal stress on early-life body size, physiology and survival in Chinook salmon, a species with differential growth and reproductive investment between sexes. We predict males will be more sensitive to a prenatal signal because they are expected to invest more in body size for mate competition. We mimicked a maternal stress signal by exposing eggs to biologically relevant doses of cortisol (low, high, control). Offspring were reared in semi-natural streams either simulating drought (stressful post-natal environment) or control water conditions. We aim to examine responses in morphometrics, physiological traits and survival within the context of whether pre- and post-natal stress exposure sex-specifically matches offspring phenotype and performance to the quality of the offspring's expected future environment.

P2-19 CURRY, JE*; NAVARA, KJ; University of Georgia; *jcurry@uga.edu*

Effects of Increased Omega-6 and Omega-3 Fatty Acids on Primary Sex Ratio in Japanese Quail, Coturnix japonicaj

Avian species have been shown to alter the primary sex ratio of their offspring in response to a variety of environmental and social factors. Food availability and quality appear to be strong influences on offspring sex ratios in birds; in 19 or 23 studies examining the influences of food availability or quality on sex ratios, a significant effect was found, and in general, more available and higher quality food stimulated the production of more male offspring. However, to date, the dietary component responsible for generating these skews is still unknown. In addition to food availability and quality, female condition, as measured by the female's fat content, is also a common predictor of offspring sex ratios in birds. Thus, we hypothesize that the fat content in a female bird's diet may be a major factor in the cause of sex ratio bias. Further, we chose to focus on omega-3 and omega-6 fatty acids due both to their well-known physiological influences in birds, and also because in a study of Kakapo parrots, the addition of seeds high in these fatty acids to the diet results in offspring sex ratios that were significantly male-biased. Adult Japanese quail were pair-housed and fed either a conventional quail diet crumble or a diet crumble containing 10% higher levels of omega-3 and omega-6 fatty acids using a 1:1 combination of sunflower and linseed oil. After a two-week adjustment period, 14 eggs were collected from each bird, eggs were incubated for 2 days, and resulting embryos were collected and sexed using molecular techniques. The results of this study will shed light on the potential mechanisms responsible for sex ratio biases in birds.

P2-242 CURTIS, KM*; MOORE, PA; MARTIN III, AL; Saginaw Valley State University, Bowling Green State Universiy; *kmcurti1@svsu.edu*

The effects of population structure on crayfish aggression

Animals readily participate in agonistic interactions that often allow them to secure or maintain access to necessary resources. Crayfish are known to fight vigorously when first introduced, with aggressive behaviors decreasing in frequency and duration as the population stabilizes. These interactions often result in dominant and subordinate relationships developing between individuals in a population. In paired interactions between crayfish of different sizes, the large animal will become dominant while he small animal will behave as a subordinate. However, populations of crayfish are more complex, contain more conspecifics, and are more difficult to assess. Mutual- and self-assessment are ways in which animals evaluate conspecifics within a population; this assessment will influence the behaviors of the focal animal as it encounters conspecifics in agonistic bouts. Some theoretical models have examined assessment strategies and aggression within populations in relation to resource value, but more empirical evidence is required to support these models. To begin to address this issue, we examined the influence of crayfish population structure on aggression with a constant number (4) of identical shelters presented to each group. Populations of animals (4 large, 4 small, 3 small vs. 1 large, 2 small vs. 2 large, or 1 small vs. 3 large) are recorded for 24-hour trials to determine fight duration and outcome. The fight duration data collected from these trials will provide strong evidence for the influence population structure has on aggression in the presence of a consistent resource (shelters). This study along with future studies on resource value will provide empirical evidence to better understand how resources and assessment strategies collectively influence the intricacies of population structure.

79-1 CYR, JL*; GAWRILUK, TR; RADA, B; WATFORD, W; SEIFERT, AW; EZENWA, VO; University of Georgia, University of Kentucky; *jennifer.cyr25@uga.edu*

Neutrophil Function, Humoral Defense, and Tissue Regeneration in Mammals

Adult mammals generally heal wounds by forming scar tissue. Howvever, African spiny mice (*Acomys spp*.) can undergo tissue regeneration to heal hair follicles, sebaceous glands, dermis and cartilage in lieu of fibrosis. It is not known why these mammals can regenerate while others cannot, but studies in non-mammalian vertebrate systems suggest regeneration is associated with reduced pro-inflammatory and cellular immune responses. In this study, we used a comparative approach to evaluate the quantity and efficacy of cellular and humoral innate immune responses in regenerating (*Acomys cahirinus*) and non-regenerating mice (*Mus musculus*). We evaluated the number and functionality of neutrophils, key inflammatory cells of innate immunity, and found that while *A. cahirinus* exhibited lower neutrophil numbers than *M. musculus* in the blood, both species contained equal neutrophil numbers in the bone marrow. We also observed that *A. cahirinus* neutrophils contained significantly less myeloperoxidase, required for producing reactive oxygen species, and exhibited increased phagocytosis compared to *M. musculus* neutrophils. Finally, we assessed the *in vitro Escherichia coli* killing abilities of neutrophils, serum, and whole blood from both species. We found that while neutrophils and whole blood from both species exhibited similar bacterial killing, the serum of *A. cahirinus* was significantly more effective at destroying *E. coli* than that of *M. musculus*. Collectively, these results indicate marked differences in neutrophil number and function between animals with differing regenerative capacities. They also suggest regenerating mice may depend more on serum defenses than cellular ones to control bacterial infection and that regenerating rodent serum may inhibit the bacterial killing ability of cells.

P1-213 CYR, S.N.*; ELLERBY, D.J.; GERRY, S.P.; MORAN, C.J.; TRUEBLOOD, L.A.; La Sierra University, Wellesley College, Fairfield University, Fairfield University; *scyr782@lasierra.edu*

Aerobic and Anaerobic Muscle Capacity in Bluegill Sunfish Ecomorphs

The bluegill sunfish (*Lepomis macrochirus*) is a freshwater fish that is commonly found in lakes and ponds throughout North America. Populations of this fish regularly diverge into littoral and pelagic forms that vary in foraging behavior, diet and body shape. These variations in phenotype may be associated with adaptation for a particular habitat. Individuals that live in the littoral zone maneuver through a complex physical environment and feed largely on invertebrates, prey found on macrophytes. Pelagic individuals feed in the open water, preying on smaller, mobile prey. The variation in both prey and structure of these environments requires reliance on different forms of locomotion and feeding. Individuals in complex littoral environments rely more on pectoral fin powered low-speed swimming, complex maneuvers to get around obstacles, and higher suction feeding pressures. Whereas individuals from the pelagic zone tend to use rapid accelerations powered by axial undulations to capture prey and avoid predators. Reliance on a locomotion or feeding type should result in variation in metabolic capacities in muscles associated with that activity. To test this hypothesis, assays of citrate synthase (a key regulatory enzyme in the citric acid cycle), and lactate dehydrogenase (a terminal enzyme in glycolysis) activity were used as a proxy for aerobic and anaerobic capacity for muscles involved in locomotion (all pectoral fin divisions and slow and fast myotomal) and suction feeding (adductor mandibulae, sternohyoid). Metabolic capacity was analyzed to quantify variation in swimming and feeding performance between bluegill from pelagic and littoral habitats. The observed variation in metabolic capacity demonstrates physiological adaptation as a result of habitat selection.

29-3 CZAPANSKIY, MF*; ADAMS, J; FELIS, J; KELSEY, EC; HINES, E; San Francisco State University, U.S. Geological Survey; *maxczapanskiy@gmail.com*

Quantifying the Influence of Energy Windscapes on Seabird Distributions

The spatial distribution of predators is often linked to their prey, but not all prey patches are of equal quality. The energetic cost of accessing a patch contributes to its value and thereby influences the spatial structure of a population. However, species distribution models often ignore the effects of movement because of the lack of methods for quantifying habitat accessibility. To close this gap, we applied the *energy landscape* conceptual model, which interprets animal movement from the cost of transport through heterogeneous environments, to analyze the influence of winds on the distribution of the Red-footed Booby (*Sula sula*), a marine predator. In May-September 2016, we tracked fifteen breeding birds at the Kilauea Point National Wildlife Refuge, HI with combination GPS/accelerometer devices. By regressing acceleration-derived energy costs against wind conditions and other variables, we developed an environmental flight cost model. This cost of transport model was applied in an anisotropic (directional) least-cost path analysis to quantify the cost of transport throughout the colony's foraging territory as a function of wind. Preliminary qualitative examination suggests the energy windscape model better predicts foraging site selection of tracked birds than a distance-to-colony null model. We will validate the method by fitting GAMs to the utilization distribution (UD) as a function of the energy windscape and null models, which we will use to predict UDs at independently tracked sites in Hawaii. We expect to find that energy windscapes quantify habitat accessibility for seabirds, which is particularly valuable for species distribution modeling of mobile organisms.

P1-258 CZECK, G*; BLAND, R; BARSCHALL, P; COHEN, CS; Romberg Tiburon Center, SFSU, California, Dept. of Biology, Physics; *gczeck@mail.sfsu.edu*

Measuring Attachment Strength in Leptasterias Sea Stars

Wave forced detachment from a substrate has fitness consequences for *Leptasterias* spp, a genus of small, brooding sea stars with low dispersal. At low tide, *Leptasterias* are found in wave-protected (pool) or wave-exposed (rocky) microhabitats. Variation in attachment strength between pool and rock stars could indicate microhabitat selection or a flexible response to environmental stress. We investigate the attachment strength of *Leptasterias* by quantifying resistance to detachment by measuring the force required to pull a star away from its substrate (a "pull"). A flexible, piano-wire clamp connected to a spring scale is used to minimize interference between the tube-feet and substrate. Pulls were recorded in the field and lab, along with the star's weight. Rock star field pulls from Pigeon Point (CA) ranged from 73-860 g (n=7), and the combined range for 2 similar WA locations was 300-2500 g (n=9). Dividing the pull force by the weight of the star gives the specific pull-strength (SPS). For rock stars, the SPS ranged from 400 to 1000, with values tightly clustered about 400-600. Wave-protected pool stars from Pigeon Point attached less strongly: 175-450 g (n=8), with SPS in the range 33-210. Larger sample sizes are needed to fully resolve the difference in attachment strength between pool and rocky microhabitats and to address the causes and limits of variation within individuals related to environmental stress. Variation in pool and rock star attachment strength may be useful for monitoring changes in Eastern Pacific coastal communities impacted by increasing physical stress from altered water quality and wave impacts.

33-4 D'AMELIO, P/B*; TER MAAT, A; GAHR, M; Max Planck Institute for Ornithology; *pdamelio@orn.mpg.de*

How Zebra Finches Chat: From Auditory Recognition to Motivation to Answer

The study of bird vocal communication has historically focused on songs, whereas the study of unlearned calls has not been given much attention. Songs are elaborate, long, and only serve few functions, whereas calls are much shorter, simpler, and are employed in a myriad of situations. For example calls are used for alarming, recruit feeding companions, signaling movement and, most interestingly, can also mediate social relationships. To fully investigate these functions it is essential to record birds continuously and individually. We therefore developed miniaturized backpack microphones to be used on a small social and monogamous bird, the Zebra Finch, to address 3 questions about calls. 1) Are the unlearned calls individually recognized? 2) How does the vocal communication develop within a pair? 3) Is the telencephalic motor vocal pathway, which controls learned vocalizations, also involved in the production of calls? We found that the calls are individually recognized allowing the sender to address specific birds within a group. Next we discovered that mates established precise and consistent patterns of alternated calling during pair formations, but not all pairs have the same strength and pattern. Finally, when considering the neural control of these unlearned vocalizations, we found that lesions of the telencephalic nuclei influenced the spectral features of these unlearned vocalizations whereas they do not influence their temporal pattern (i.e. duetting with the partner). We were able to successfully characterize the calling system of a Passeriform at multiple mechanistic levels, from motor control to call motivation in carefully controlled situations. We are now convinced that our results provide a basis for future scientists to study calling interactions in wild populations to understand their influence on pair compatibility and ultimately fitness success.

P2-45 DADDINO, AB*; DIAMOND, KM; PENROD, L; JOHANSEN, JL; STEFFENSEN, JF; DOMENICI, P; Univ. of San Francisco, Clemson Univ., Florida Institute of Technology, UT Austin Marine Science Institute, Univ. of Copenhagen, IAMC-CNR Oristano; *abdaddino@dons.usfca.edu*

Does the Form of Stress Matter? A Comparison of Pacific Sand Lance (Ammodytes hexapterus

The Pacific sand lance (*Ammodytes hexapterus*) is a pelagic schooling species that is capable of burrowing in sandy substrates. Observations of wild caught sand lance revealed an unusual behavior where fish exhibit suspended animation lying on the bottom of a tank without burrowing; a behavior we term the 'Lazarus effect'. We were interested in examining which types of stress cause the Lazarus effect and if fish would perform this behavior on sandy substrates. Sand lances were exposed to either physiological (hypoxia at 20% oxygen saturation) or mechanical (a chase protocol) stressors, both of which were compared to an unstressed group. We also replicated experiments with and without a sandy substrate. We predicted that fish exposed to either stressor would be less likely to actively swim when compared to unstressed fish. As burrowing has been described as an anti-predator defense, we also predicted that fish exposed to mechanical stressors would bury more often and fish exposed to physiological stressors as this stimuli would be more similar to a predator attack. Preliminary results suggest that when sand is present, stressed fish are more likely to respond with the Lazarus effect or swim actively regardless of the type of stressor. However, when we ran trials without sand, mechanically stressed fish swam actively, while physiologically stressed fish were more likely to show the Lazarus effect. These results suggest sand lances can respond uniquely to different forms of stressors, which could allow for their continued success in high stress environments.

P2-163 DAHLHOFF, VC*; LARKIN, BG; JACKSON, M; WOODS, HA; University of Montana, MPG Operations; *victoria.dahlhoff@umontana.edu*

Thermal advantages of large colony size in the western tent caterpillar Malacosoma californicum pluviale

Animal colonies range from loose aggregations of largely unrelated individuals to tightly organized, closely related groups with reproductive division of labor. A key characteristic influencing this variation is the number of individuals colonies contain. Although factors affecting colony size have been explored, to date there have been relatively few studies exploring how colony size affects the temperature and performance of colonies as a whole, with performance gauged by growth and mortality rates. Using the western tent caterpillar, Malacosoma californicum pluviale, I examined the effects that different colony sizes had on tent temperatures and larval growth and mortality rates. Tent caterpillars build communal silk tents, which act as an extended phenotype and that may allow them to modify their local microclimates. I predicted that large colonies would build larger, warmer tents more rapidly, allowing larvae to grow faster in cool spring conditions. To test this prediction, I manipulated colonies of the western tent caterpillar (10, 50, 100, 150 individuals) at a site in Condon, MT, and examined the differences in growth rates, mortality rates, and tent temperatures. Larvae from larger colonies grew to their final instar 30% faster than did those from smaller colonies, most likely because their tents reached temperatures up to 22C higher than air temperatures, 15C higher than the smaller colonies. Also, no larvae from smaller colonies but 16% of larvae from larger colonies survived to pupation. Together, these results indicate positive selection on colony size in the wild. I discuss several life-history constraints, and potential opposing selective factors, that may prevent the evolution of larger size.

38-4 DAKIN, R.*; SEGRE, P.S.; STRAW, A.D.; ALTSHULER, D.L.; University of British Columbia, University Freiburg ; *roslyn.dakin@gmail.com*

Hummingbird evolution reveals the biomechanical organization of maneuverability

How does maneuverability evolve? A challenge to understanding maneuverability is that it encompasses diverse and transient behaviors. We used machine vision to record thousands of flight maneuvers by over 200 hummingbirds from 25 different species, to evaluate the influence of shared biomechanical traits. There are two benefits of this comparative approach: (1) evolution has repeatedly altered different traits in different species, making it possible to disentangle the effects of multiple traits; and (2) by capturing variation within multiple species, we can evaluate as in a meta-analysis whether the effects of trait variation within species are consistent. Our analysis identifies correlated clusters of performance: one that includes translations and pitch upward rotations, dependent on species muscle capacity, and one that includes downward and yaw rotations and the use of complex turns, dependent on species wing loading. We also find that the use of two different types of complex turns, smooth arcing turns and sharp pitch-roll turns, is associated with the elevational environment, morphology, and skill. Together these results show that macroevolutionary changes in muscle and wing morphology affect different, correlated maneuvering behaviors, and that species and individuals play to their strengths.

133-6 DALE, KE*; MEHTA, RS; Univ. of California, Santa Cruz; *kdale@ucsc.edu*

Morphology affects dispersal of eel larvae in the Eastern Pacific

The persistence of marine fish populations is strongly influenced by ocean currents, which conspire to disperse or retain planktonic larvae. Larval mobility is influenced by factors such as pelagic larval duration time, swimming ability, growth rate, body shape, and abiotic factors such as current patterns. Eels and their relatives (superorder Elopomorpha) possess a unique, leaf-shaped, flattened larval form called a leptocephalus. These larvae exhibit the highest growth rates and longest pelagic duration times of any fish. The Eastern Pacific hosts a large number of taxa, which exhibit a diversity of larval forms.. Determining larval distributions as well as how larval morphology affects dispersal is an important step in understanding distribution patterns of elopomorph fishes. Long-term catch data from the California Cooperative Oceanic Fisheries Investigations program (CalCOFI) were used in conjunction with morphological data provided by NOAA's Southwest Fisheries Science Center to examine spatial trends in light of abiotic and biotic factors. We found that larvae were caught more frequently in waters warmer than expected for a given location, and that the geographic range of larval catches was broader in years following an El Nino Southern Oscillation event. Larval body length and body depth were significant predictors of location, and larvae with smaller aspect ratios (shorter and deeper) were found further north. Catch data clearly indicates that Baja, Mexico peninsula is a major spawning location. In light of these findings, we conclude that,a significant negative trend between aspect ratio and latitude ratios indicates that shorter, deeper body shapes may allow for an increased capacity for dispersal. Our results support the hypothesis that El Nino events slow the southward-flowing California Current and allow larvae to move north.

S5-9 DALEY, MA*; GORDON, JC; BIEWENER, AA; SPRöWITZ, A; Royal Veterinary College, Harvard University, Max Planck Institute; *mdaley@rvc.ac.uk*

Understanding the agility of running birds: Sensorimotor and mechanical factors in avian bipedal locomotion.

Birds are a diverse and successful class of vertebrates with exceptional locomotor agility and ecological range, capable of many combinations of aerial, terrestrial, and aquatic locomotion. Despite great diversity, birds all share a consistent bauplan and rely on bipedal locomotion for at least part of their life history. Thus birds provide a valuable opportunity to investigate how body size and locomotor ecology influence the biomechanics and sensorimotor control of bipedal gait. Bipedal animals must precisely control limb-substrate interactions to move effectively over varied and uncertain terrain while avoiding injury. One key source of uncertainty is sensorimotor delay that limits feedback response times. This delay necessitates effective integration of intrinsic mechanics with predictive and reactive sensorimotor control mechanisms. My research team study non-steady locomotor behaviours to understand how birds effectively integrate mechanics and sensorimotor control. We collaborate with robotics engineers to test control principles inferred from avian studies. In this talk, I will discuss specific limb control mechanisms used by birds to achieve agile and stable gait, and functional trade-offs that likely influence scaling of gait with body size. I will highlight specific morphological and sensorimotor specializations of birds that might help explain their exceptional locomotor agility. In ongoing work, we are investigating perching balance control, to understand how balance sense is integrated with proprioception, spinal neural circuits and intrinsic leg mechanics. We hope the principles revealed from these studies will lead to bird-inspired control strategies for agile autonomous robots.

P1-46 DANOS, N; University of San Diego; *ndanos@sandiego.edu*

Pregnancy effects on muscle function.

Pregnancy is a metabolically demanding condition in mammals that directly affects individual fitness. Most pregnant animals must remain active to avoid predators and secure increased food demands. However, during pregnancy hormonal effects alter the morphology and material properties of muscle-tendon units that are key during locomotion. The effect of these changes is not at all well understood despite its significance to mammalian evolution and public health. Using the rat as an animal model, I measured morphological and mechanical properties of the gastrocnemius muscle that have been shown to be significant contributors to muscle-tendon function. I found that both the longitudinal Young's modulus of connective tissues such as the aponeurosis and muscle mass relative to total body mass both decreased by a factor of 1.3. A computational model of muscle-tendon interactions is used to explore the effect of these changes on cyclical muscle contractions that simulate walking on flat, incline and decline surfaces and compare these with three-dimensional high-speed video data of animals walking under these conditions to examine the effects of pregnancy at multiple levels of organization. Preliminary results suggest that the total force produced by a muscle-tendon unit of a pregnant animal during optimally activated work loops drops by 46% compared to contractions in a non-pregnant animal. This drop is entirely due to the change in maximum magnitude and dissipation profile of the passive force, while the maximum active force produced by both the pregnant and non-pregnant muscles remains unchanged. These results suggest that pregnancy-induced morphological and mechanical changes may limit the capacity of muscles to utilize elastic energy storage and may change where muscles operate on the force-length curve *in vivo*.

P2-221 DANSEREAU, KT*; BONACKER, KL; KINNEY, SR; KRANS, JK; Western New England University; *jkrans@wne.edu*

Efficacy of transient RNAi against the largest gene in Drosophila, the titin analog sallimus (a giant sarcomere associated protein)

We report here on the efficacy of transient RNAi against the sallimus (sls) gene in the fruit fly, *Drosophila melanogaster*. The sallimus gene encodes a number of giant sarcomere associated protein (gSAP) isoforms, several of which are expressed in larval muscle. We designed a transient construct that utilizes the temperature sensitive yeast transcription enzyme Gal80^{ts} to regulate Gal4-UAS promotion of dsRNA against sls. Although we have reported previously on the physiologic outcomes of this construct, this is the first time we present thorough transcriptional and translational evidence of its efficacy. We used qPCR, western blot of protein isoforms, and immunohistochemistry to probe complementary sites along the sls gene / protein. Since sls is the longest gene in the fly (>1 Mbp), as titin is the longest gene in mammals with which we are familiar, the action of the RNAi construct was somewhat different than anticipated in two main ways. (1) The construct required exposure to restrictive temperatures (31° C) for substantially longer than originally anticipated (~16 hours). (2) The reduction in expression of sls was not uniform across its length or isoforms; exons nearest the site of dsRNA were reduced significantly ($p < 0.01$) whereas those furthest from it were not. Nevertheless, expression of exon regions of interest such as the putative N2A analog were significantly reduced, permitting useful physiologic tools for the investigation of gSAP / titin physiology. We hope others will adopt this model for future mechanistic investigations of titin as well as comparative work to better understand the role gSAP molecules like titin play across Animalia.

94-1 DANTZER, B.*; WESTRICK, S.E.; MONAGHAN, P.; BOUTIN, S.; HUMPHRIES, M.M.; LANE, J.E.; MCADAM, A.G.; VAN KESTEREN, F.; University of Michigan, University of Glasgow, University of Alberta, McGill University, University of Saskatchewan, University of Guelph; *dantzer@umich.edu*
How does maternal stress affect offspring oxidative signaling and telomeres in wild North American red squirrels?
Ecological factors such as intraspecific competition, predation risk, food availability can induce variation in maternal stress hormone levels. These changes in maternal stress hormones may induce adaptive stress-mediated maternal effects on offspring characteristics that increase the ability of offspring to survive in stressful or anticipated environments. Alternatively, the benefits of stress-mediated maternal effects may attenuate as offspring age and/or the environment changes. We examined how experimental increases in maternal stress hormones in North American red squirrels (*Tamiasciurus hudsonicus*) in the Yukon, Canada affected offspring postnatal growth and oxidative signaling. We treated pregnant females with exogenous glucocorticoids or a control treatment and identified their effects on the following in their offspring: a) growth, b) antioxidants (TAC and SOD) and c) oxidative damage (protein carbonyls) in the blood, liver, and heart, and d) telomere lengths in the liver. We present the results from this three-year field experiment and describe whether stress-mediated maternal effects in red squirrels have beneficial effects on offspring growth early in life but carry costs on their rate of physiological senescence and lifespan.

P1-168 DANZIGER, A*; PELLETIER, G; FREDERICH, M; Univ. of New England, Biddeford; *mfrederich@une.edu*
Implementation of a simple low-cost nearshore plankton collection method to quantify invasive crustacean larvae
Invasive crustaceans, such as *Carcinus maenas* and *Hemigrapsus sanguinaeus*, have a significant and detrimental effect on coastal intertidal areas. We performed a 5 year monthly population analysis in a transect in southern Maine and found stable populations of both species, while similar studies in warmer areas report that *H. sanguinaeus* typically outcompetes and displaces *C. maenas*. In order to explain the coexistence of both species, the timing of larvae release, and the potential to settle in the intertidal area we performed nearshore plankton collections in close proximity of the intertidal transects. Conventional plankton tows are difficult in shallow nearshore waters, as boats can often not be used. Therefore, we designed a remote controlled boat with a plankton suction device that can be deployed in shallow waters. The plankton suction device is comprised of a 60 cm 4 inch acrylic pipe with a BlueRobotics T100 thruster, 200 µm plankton filter, and a General Oceanics mechanical flowmeter. 3D printed components were made to assemble the individual parts. The plankton suction device was then connected 30 cm underneath a remote controlled boat. This RC boat can be launched from the shore in shallow water and allows for collection of plankton samples in waters poorly accessible by boat based plankton nets. Samples collected with the RC boat-driven plankton sucker, as well as traditional boat deployed plankton nets were analyzed using a FlowCam particle imaging system. There were no differences between both sampling methods. The analysis of planktonic zoea larvae of *C. maenas* and *H. sanguinaeus* close to the 5 year transect site is ongoing. Supported by NSF grants MRI-1624984 and IUSE-1431955 to M.F.

4-1 DARBY, AM*; PATTON, SA; GIBBS, AG; Univ. of Nevada, Las Vegas, Nevada State College; *darbya1@unlv.nevada.edu*
Gut Microbiome Effects on Desiccation Resistance in Drosophila melanogaster
The microbiome is the collection of microorganisms that occupy an individual's skin and intestines, and it has many potential effects on an animal's physiology. Changes in the microbiome affect an organism's ability to tolerate certain stressors such as desiccation. To our knowledge, no study has yet examined whether gut bacteria have any impact on an organism's ability to tolerate dry conditions, which is important to understand how animals may react to a drier climate. The Gibbs lab has selected for desiccation resistance in replicated populations of *Drosophila melanogaster* for over 225 generations, resulting in desiccation-selected (D) flies that survive desiccation ~50% longer than fed control (F) flies. D and F flies had similar numbers of gut bacteria. We generated axenic flies by washing embryos with bleach and rearing them on sterile media. Axenic D and F flies survived desiccation stress ~20% longer than non-sterile controls. Axenic flies did not lose water more slowly than non-sterile controls; instead they were larger and contained more water. Our results suggest that the gut microbiome may affect insect survival in arid environments. Supported by the McNair Scholars Institute at UNLV and an REU supplement to NSF award IOS-1355210.

P2-254 DARWISH, ZL*; CUNNINGHAM, KM; STRASSER, R; University of Nebraska Omaha; *zdarwish@unomaha.edu*
Influence of Rearing Condition on Adult Social Behavior in Zebra Finches
Social interactions are critical for normative development across species. Zebra finches (*Taeniopygia guttata*) are a highly social songbird that interact both at a pair and flock level. Adolescent social experience with conspecifics is necessary for the development of species-typical social behavior in zebra finches. In the present experiment, zebra finch chicks were raised by either both parents (biparental) or their mother only (uniparental) to assess the impact of differences in rearing environment on adult social behavior. After reaching adulthood, male (n = 10) and female (n = 9) zebra finches were released into an aviary equipped with two feeding stations that recorded individual ID numbers. During the 22 day data collection period, there were 20,658 recorded visits to the feeding stations, representing 2,045 co-feeding events. Data were analyzed using social network analysis to examine connectedness among flock mates. Male finches raised in the biparental condition demonstrated a trend for increased social integration compared to males raised in the uniparental condition, as assessed through weighted degree (a measure combining the number of associations an individual has and the proportion of co-feeding events shared with each flock mate). Female finches demonstrated no difference in weighted degree based on rearing condition. These findings indicate that differences in rearing environment have a long-term impact on social foraging behavior in male, but not female, zebra finches.

P3-92 DAVIDSON, B.A.*; WENKER, E.; MALISCH, J.L.; St. Mary's College of Maryland; *jlmalisch@smcm.edu*

Fat Score Predicts Acute Stress-induced Hyperglycemia in White-throated Sparrows

Glucose mobilization is a classically listed and presumably adaptive physiological response to acute stress. However, this hyperglycemic response is not ubiquitous, particularly among non-mammalian vertebrates. Here we characterized the glycemic response to acute-handling stress in an overwintering, free-living, population of birds: white-throated sparrows (*Zonotrichia albicollis*) in St. Mary's County, Maryland. As part of this experiment we validated a novel technique for rapid field measurements of glucose: utilization of a human blood glucose meter, FreeStyle Lite®. Measurements with the meter were strongly correlated to those acquired using a colorimetric assay kit. Furthermore, acute-handling stress elevated blood glucose at both 15 and 30 min post-capture as compared to baseline. This result is consistent with both the mammalian literature as well as our previous work on white-crowned sparrows during the breeding season. Finally, body condition, particularly abdominal fat score, was significantly positively correlated to stress-induced blood glucose after 30 min of handling stress. This result suggests that fat stores are predictive of glucose mobilization capacity in pre-migratory white-throated sparrows.

P2-206 DAVIS, AL*; MILLER, LA; Univ. of North Carolina, Chapel Hill; *a96davis@live.unc.edu*

Force Generation by the Horseshoe Crab (Limulus polyphemus)

Horseshoe crabs (*Limulus polyphemus*) mate in the surf zone where they are subjected to strong currents and waves. The strong currents can flip the horseshoe crab, exposing its ventral tissues to predation and desiccation. One possible way to prevent flipping is for the shell to produce negative lift (or minimal positive lift) in flow. Elucidating what forces are generated by the shell in flow may inform the engineering design of manmade structures that require lift reduction, as well as improve our understanding of the adaptive morphology of the shell. To quantify flow over the shell and the forces generated, we digitally reconstructed a 3D horseshoe crab using a laser scanner and a juvenile horseshoe crab molt. With the digital file, we 3D printed a physical horseshoe crab model for use in particle image velocimetry (PIV). PIV allows us to experimentally visualize the flow structure for comparison to simulations. The results of the experiment will be used to validate numerical simulations using the immersed (IB) boundary method. The IB simulations will then be used to quantify the forces produced, particularly lift and drag which are essential to understanding flipping. When done across a sweep of angles of attack, PIV and IB together will give a much fuller picture of the forces imparted on and the flow structure around the horseshoe crab than has previously been published.

P3-242 DAVIS-BERG, EC*; ROCK, MO; RAMIREZ, I; WILSON, BA; Columbia College Chicago, University of Illinois at Chicago and Garfield Park Conservatory, Liberty Public Schools; *edavisberg@colum.edu*

Succession and climate change - can molluscs be indicators?

Long-term changes due to succession and climate change were assessed for the molluscan fauna in a re-established forest ecosystem. The Fitch Natural History Reservation located in Douglas County, Kansas was founded in 1948. Prior to the foundation of the reserve, the non-forested areas were heavily cultivated or grazed. From the late 1940s through the 1950s, many surveys of molluscan fauna were completed. It has since been allowed to undergo natural succession, returning to a primarily forested ecosystem. In some areas of the reserve, succession has caused a rapid increase foliage resulting in a dense underbrush over the last 10+ years. These surveys have provided a species list by location along with information on the local ecology at the time. To see how succession has changed the fauna at the University of Kansas Fitch Natural History Reservation, we have sampled four sites (three terrestrial and one aquatic) with periodic collections spanning 2004-2017. Species composition and diversity was then compared with the historic data. These results allow us to see how the molluscan fauna has responded to succession and climate change on this reservation over the last 50+ years. We are able to document changes in the species composition from the original surveys.

P1-282 DE KAT, R*; FEO, TJ; University of Southampton, UK, Smithsonian Institution, Washington, DC; *r.de-kat@soton.ac.uk*

Flight feathers: Barb angle variation along vane width and its relation to flight.

Flight feathers are the unique feature that enable birds to excel in flight and allow them to conquer the sky. Unfortunately, how flight feathers function has not yet been fully figured out. One mystery is how the morphological features of a feather relate to its aerodynamic performance. In particular, barb angle (as measured near the rachis) has been shown to correlate with feather function within the wing and not with vane asymmetry (Feo, Field, Prum, 2015, Proc. Roy. Soc. B 282:20142864, doi: 10.1098/rspb.2014.2864). However, one complicating factor is that many barbs are curved, and thus barb angle - with respect to the rachis - can vary across the width of feather vanes (Feo, Simon, Prum, 2016, J. Morphol. 277:995-1013, doi: 10.1002/jmor.20552). Therefore, to capture a more complete insight into barb angle variation and its relation to flight, we imaged flight feathers from species spanning the phylogenetic diversity of modern birds. These images were processed to obtain barb angles values across the width of the vane for two locations along the vane. This allows us to relate barb angle variation across feather vanes to flight style and feather function.

78-2 DE MEYER, J*; BELPAIRE, C; VAN WASSENBERGH, S; HERREL, A; MAES, GE; DIRKS, RP; BOECKX, P; BERVOETS, L; COVACI, A; MALARVANNAN, G; DHAENE , J; ADRIAENS, D; Univ. of Ghent, Belgium, Institute for Forest and Nature Research (INBO), Museum National d'Histoire Naturelle, Paris, Museum National d'Histoire Naturelle, Paris, Univ. of Leuven, Belgium, Univ. of Leiden, the Netherlands, Univ. Of Antwerp, Belgium, Centre for X-ray Tomography, Ghent; *jendmeye.demeyer@ugent.be*

Head Shape Dimorphism in European Eels … the What, How and Why Story

Since the early 20th century, head shape dimorphism in European eel was documented, but it was only in the early 21st century that statistical support for the two morphotypes was provided. Most prominent at the yellow eel stage, broad-headed eels are known to feed more on harder and larger prey than their narrow-headed conspecifics, as well as they show different foraging behaviour. The onset of this dimorphism could be traced back to the earlier glass eel stage, where both phenotypic plasticity responses to different diets as well as genetic mechanisms seem to control for it. Although the underlying musculoskeletal differences in the feeding apparatus suggest that broad-heads show adaptive modifications to deal with larger and harder prey, the integration of multiple lines of evidence suggest the story is more complex, also including aspects of differential growth rates and habitat preference. Paradoxically, the adaptive benefit of broad-heads in a natural environment actually becomes maladaptive as this environment increasingly became polluted. Dimorphic bio-accumulation of especially highly lipophilic pollutants may even compromise the reproductive success of broadheads.

P2-23 DEAL, C*; TAMONE, ST; University of Alaska Southeast; *sltamone@alaska.edu*

Purification and characterization of vitellogenin from ovaries of the protandric shrimp Pandalus platyceros

Vitellogenin is a protein synthesized and secreted from the hepatopancreas of crustaceans during ovarian maturation. Vg is taken up by ovaries and is modified to vitellin (Vn) during maturation; it is the yolk-protein that will nourish the developing embryos. We are purifying Vg from the Northern spot prawn (*Pandalus platyceros*) as a first step to developing a homologous ELISA with which to study the reproductive physiology of this species. *P. platyceros* is a commercially important protandric shrimp species and as such transforms from a small functional male to a much larger functional female. Our objective is to develop a non-lethal method with which to study physiological changes associated with this sexual differentiation. We are interested in the onset of vitellogenesis in the transitional stage. *P. Pandalus* ovaries were homogenized and proteins separated using 25%, 40%, 50% and 60% ammonium sulfate precipitation. The 50% ammonium sulfate fraction was enriched in a protein we suspect is Vg or Vn. After dialysis to remove excessive salts, proteins were separated using 10% SDS-PAGE. Western blot analysis using a heterologous antibody showed two major proteins that could be subunits of a larger protein with approximate molecular masses of 92 and 105 kD. Native gel electrophoresis using 8% PAGE revealed a large protein with an approximate molecular mass of 230 kD. Polyclonal antibodies will be generated against this protein and used to develop a homologous ELISA.

P3-150 DEAN, MN*; BIZZARRO, JJ; CLARK, B; UNDERWOOD, CJ; JOHANSON, Z; MPIKG, UC Santa Cruz and NMFS, Core Res. Labs, NHM, Birkbeck Coll., Dept Earth Sci., NHM; *mason.dean@mpikg.mpg.de*

Large batoid fishes frequently eat stingrays despite skeletal damage

The shapes of vertebrate teeth are often used as hallmarks of diet. We demonstrate, however, evidence of frequent piscivory by cartilaginous fishes with pebble-like teeth that are typically associated with durophagy, the eating of hard-shelled prey. High-resolution micro-computed tomography observation of a jaw specimen from one batoid species and visual investigation of those of two additional species reveal large numbers of embedded stingray spines, arguing that stingray predation of a scale rivalling that of the largest carnivorous sharks may not be uncommon for large, predatory batoids with rounded, non-cutting dentition. Our observations demonstrate that tooth morphology is not always a reliable indicator of diet and that stingray spines are not as potent a deterrent to predation as normally believed. In addition, we show that several spines in close contact with the jaw skeleton of a wedgefish (*Rhynchobatus*) have become encased in a disorganized mineralized tissue with a distinctive ultrastructure, the first natural and unequivocal evidence of a callus building response in the tessellated cartilage unique to elasmobranch skeletons. Our findings reveal sampling and analysis biases in vertebrate ecology, especially with regard to the role of large, predatory species, while also illustrating that large body size may provide an escape from anatomical constraints on diet (e.g. gape size, specialist dentition). Our observations inform our concepts of skeletal biology and evolution in showing that tessellated cartilage—an ancient alternative to bone—is incapable of foreign tissue resorption or of restoring damaged skeletal tissue to its original state, and attest to the value of museum and skeletal specimens as records of important aspects of animal life history.

100-8 DEAROLF, J.L.*; MCLELLAN, W.A.; PABST, D.A.; HERMANSON, J.W.; HENDRIX COLLEGE, CONWAY, AR, UNIV. OF NORTH CAROLINA AT WILMINGTON, CORNELL UNIVERSITY, ITHACA, NY; *dearolf@hendrix.edu*

Regional variation in the fiber-type profile of the bottlenose dolphin diaphragm

Currently, the role, if any, of the primarily slow-twitch (65%) diaphragm in the explosive inhalation (< 0.03 seconds) of bottlenose dolphins, is still unknown. In other mammals, the diaphragm has been shown to exhibit regional variation in fiber-type profile, and these differences in fiber composition have been related to other functions of the diaphragm. Thus, the purpose of this study is to investigate regional variation in the fiber-type profile of the bottlenose dolphin diaphragm, in order to better understand the functions of this muscle. To achieve this goal, sections of the dolphin diaphragm from the middle (M) and lateral edge (L) of the costal region, ventral to the esophagus (E), ventral to the caval foramen (C), and near to the dorsal edge (D) were cut and stained for their myosin ATPase activities. Digital images of the stained sections were captured and printed, and the numbers of slow- and fast-twitch fibers were counted on each image. These data were used to calculate the average percentage of slow-twitch fibers in each region of the diaphragm. A mixed statistical model demonstrated that there is significant variation in fiber-type profile between the different diaphragm regions. The E region possessed significantly more slow-twitch fibers by count than the C, L, and M regions, a result that suggests this region of the diaphragm acts as a sphincter to prevent regurgitation of prey. However, overall, the diaphragm of bottlenose dolphins is composed primarily of slow-twitch fibers (range: 63% to 82%). Thus, the regions of this muscle may work together to play a role in ventilation by acting as a spring or to decouple ventilation and locomotion while these animals dive on a breath-hold.

P1-261 DEBAN, SM; Univ. South Florida; *sdeban@usf.edu*
Exploring Muscle-Spring Performance in a Web-Based Simulation
Muscle Explorer simulates the performance of a simple musculoskeletal system in which a muscle shortens against an elastic element in series with a mass. The model can be used interactively in a web browser to explore a wide range of muscle-tendon behaviors, for example to predict results of in-vitro muscle experiments or the performance of explosive movements such as jumping or striking. The model simulates the interaction of several adjustable elements: a muscle-like actuator, a viscous damper, an inertial muscle mass, a hookean spring, a massless lever with a variable mechanical advantage, and an inertial projectile mass. Output is in graphical and numeric form. To simulate a movement, the physiological and biomechanical parameters of the model are set and the muscle is activated. The muscle builds force that stretches the spring. Recoil of the spring rotates the lever and accelerates the projectile mass. The muscle generates force using realistic force-velocity and force-length properties for vertebrate skeletal muscle, and the physics of the movement are modeled using a fourth-order Runge-Kutta integrator. The muscle consists of three subcomponents: (1) the muscle actuator produces force based on shortening velocity, length, and excitation level, (2) an inertial mass that is accelerated by the balance of actuator and spring forces, and (3) a viscous damper that opposes movement of the mass. The tendon component attached to the muscle component is a hookean tension spring that links the muscle to the appendage and the projectile mass. A latch prevents the lever from rotating as the spring exerts force on the lever; it can be released under specified conditions. The model is implemented in JavaScript, CSS and HTML at http://knot.cas.usf.edu/Musclemodels/muscleexplorer.html and is intended for use in research and teaching.

P2-109 DEBIASSE, M*; FRANCIS, W; THUESEN, E; HADDOCK, S; RYAN, J; University of Florida Whitney Lab for Marine Bioscience, Ludwig-Maximilians-Universität München, The Evergreen State College, Monterey Bay Aquarium Research Institute; *melissa.debiasse@gmail.com*
DEEPC: The deep, dark, genomic secrets of ctenophores
Over evolutionary timescales, many marine taxa have made transitions to and from the deep sea. Shallow and deep-sea habitats vary drastically in several environmental variables including light, temperature, oxygen concentration, pressure, and pH. Ctenophores, also called comb jellies due to their large ciliary paddles arranged in "comb rows," are monophyletic but deep and shallow species are spread across the ctenophore phylogeny, suggesting transitions from deep to shallow and from shallow to deep have occurred multiple times. To understand the evolutionary pressures that drive adaptation to extreme environments, we collected 35 ctenophore species with representatives from a diverse set of ctenophores with habitats ranging from surface waters to 4000 meters deep. Our process involves sequencing and assembling transcriptomes, defining orthologs, estimating phylogenies, detecting positive selection, and identifying convergence in protein sequences. Using these data we are determining: (1) the phylogenetic relationships among these species, (2) the evolutionary lineages where depth transitions have occurred, (3) the depth range for the ancestral ctenophore and (4) the evolutionary genetic changes that have allowed species to adapt to shallow and deep sea habitats. This work uncovers a great mystery of how animals can adapt to extreme environments, and will provide a baseline of deep-sea ctenophore biodiversity, which will be important for understanding ecological change in the face of anthropogenic stressors.

52-3 DEBIć, S; University of Zagreb, Faculty of Natural Science and Mathematics; *sara@debic.org*
Chasing Diversity: Phylogenetic Assessment of Central Philippine Sea Pens
Octocorals are a diverse group of, for the most part, non-reef building corals accounting for almost 65% of global coral diversity. Sea pens are a highly specialized group of octocorals inhabiting both shallow and deep water ecosystems. The evolutionary origin of sea pens and their interspecies relationships have historically been a point of contention among zoologists, with only recent molecular methods being able to elucidate systematic relationships. Here we present a molecular analysis of six sea pen genera alongside representatives from the Calcaxonia, Scleraxonia, Holaxonia, and soft coral groups using the NADH 2, NADH 6, and msh1 mitochondrial genes. All specimens were collected in the central Philippines, which is an extremely high marine biodiversity area. We found the sea pens to be monophyletic with the calcaxonian family Ellisellidae, confirming previous studies. We also found the sea pen genera *Veretillum* and *Cavernulina* to be highly derived within the sea pen clade, refuting past hypotheses that Veretillid sea pens are among the least derived. Instead, our analysis shows the genus *Virgularia* with well differentiated polyp leaves to be the most basal. Because the sea pen clade is monophyletic with the Ellisellids, which inhabit shallow to mid-deep water, further studies are aimed at investigating whether the sea pens originated and diversified in the shallows and subsequently adapted to deep water ecosystems. A comprehensive sampling of both sea pens and calcaxonians from all depths is the next step in investigating the origin and radiation of sea pens, giving us valuable information about adaptations to different bathymetric environments in an age with rapidly rising sea levels.

P1-132 DEBRY, RW*; WONG, ES; DAHLEM, GA; Univ. of Cincinnati, Northern Kentucky Univ.; *ron.debry@uc.edu*
Delimiting Imaginary Species in the Fly Genus Ravinia
DNA-based analyses hold the promise of bringing repeatability and objectivity to the process of species delimitation, with the caveat that DNA-based delimitation decisions should be limited to instances where multiple types of analysis provide a coherent picture. The morphologically defined species *Ravinia anxia* and *R. querula* (Diptera:Sarcophagidae) have a long history of fluid (and even erroneous) species definitions and, thus, seem a logical candidate for application of DNA-based approaches. We examined DNA sequence data from two regions of the mitochondrial genome plus fragments of five different nuclear protein-coding genes, sampled from 30 individuals from across much of the geographic range of the two morphological species. Population genetic and phylogenetic approaches, including both discovery-based and validation-based methods, all agreed on the presence of three highly distinct evolutionary lineages. One lineage included only flies morphologically assigned to *R. anxia* and one included only flies morphologically assigned to *R. querula*. The third lineage, however, included flies morphologically assigned to both *R. anxia* and *R. querula*. Careful follow-up morphological examination of the specimens from the "mixed" lineage both reaffirmed the original species assignments and failed to discover any morphological feature uniquely shared by members of the mixed lineage. We thus conclude (for now) that the DNA-based species delimitation approaches may be capturing some retained ancestral polymorphisms, and that the two-species morphological definitions should be retained.

97-3 DEETJEN, ME*; LENTINK, D; Stanford University; *mdeetjen@stanford.edu*

High-Speed Surface Reconstruction of Flying Birds Using Structured Light

Birds fly effectively through complex windy environments, and in order to understand the strategies that enable them to do so, we need to determine the shape and movement of their wings. Previous studies show that even small perturbations in wing shape have dramatic aerodynamic effects, but these shape changes have not been quantified automatically at high temporal and spatial resolutions. Hence, we developed a custom 3D surface mapping method which uses high-speed cameras to view optimized grids of stripes projected onto a flying bird. By matching the stripes seen in each camera frame with the projected stripes, we can triangulate the 3D bird surface along the grid lines. Because the light is binary rather than grayscale, and each frame is separately analyzed, this method can capture rapidly moving objects at any frame rate, as long as the camera captures sufficient light contrast. In addition, the method is automated, non-invasive, and capable of measuring a shape volume by simultaneously reconstructing from multiple view angles. We use this technique to reconstruct the 3D surface of a parrotlet during flapping flight at 3200 fps. From this shape we can extract the airfoil, velocity, and angle of attack which allows us to analyze key dynamic parameters such as lift and drag. While this novel system is designed to quantify bird wing shape and motion, it is adaptable for tracking other quickly deforming objects including other animals, especially those which are difficult to reconstruct using other 3D tracking methods.

100-5 DEL CARLO, RE*; REIMCHE, JS; HAGUE, MTJ; BRODIE,JR., ED; LEBLANC, N; FELDMAN, CR; Univ. of Nevada, Reno - School of Medicine, Univ. of Nevada, Reno, Univ. of Virginia, Utah State Univ.; *rdelcarlo@med.unr.edu*

Performance costs of adaptive resistance to tetrodotoxin in the Newt-Snake coevolutionary arms race

The interaction between toxic newts (*Taricha*) and resistant garter snakes (*Thamnophis*) is a model system of predator-prey coevolution. Pacific newts defend themselves with the potent neurotoxin, tetrodotoxin (TTX). TTX specifically binds to the outer pore of voltage-gated sodium channels, Na_V proteins. These proteins are responsible for the first electrical event initiating every action potential and every skeletal and cardiac muscle contraction. TTX-ligation to the channel pore prevents sodium ion movement through the membrane, thereby abolishing excitability, and leading to numbness, paralysis, and eventually death by respiratory arrest. TTX serves as an agent of selection on at least three species of *Thamnophis* that prey on sympatric *Taricha*. *Thamnophis atratus*, *couchii*, and *sirtalis* have independently evolved adaptive mutations within the pore of the skeletal muscle channel variant, $Na_V1.4$. The amino acid substitutions reduce the affinity of TTX to the pore, thereby providing physiological resistance to TTX. Here, we discuss how these same mutations may actually reduce sodium channel performance. We show that animals carrying these mutations display diminished skeletal muscle performance. This hypofunction is likely explained by alterations to biophysical properties of the channel, such as the sodium-selectivity or total sodium current through the membrane. We investigate channel hypofunction through site-directed mutagenesis, constructing the naturally occurring TTX-resistant mutations and contrasting these to a TTX-sensitive template. We then assess the behavior of mutant sodium channels by patch clamp electrophysiology to reveal interesting support for this biophysical tradeoff.

P1-194 DEL RIO, AM*; DAVIS, BE; KUELTZ, D; TODGHAM, AE; Univ. of California, Davis; *amdelrio@ucdavis.edu*

Effects of High Temperature and Low Oxygen on Early Life Stage Chinook Salmon Survival and Physiology

Climate change and drought can lead to increased temperature and decreased dissolved oxygen in rivers. In the Central Valley, rivers are typically managed for salmonid survival based on temperature; however, oxygen saturation is another critical factor for managers to consider. Salmon embryos are particularly susceptible to high temperatures and low oxygen given that conditions within a redd, or nest, can differ from those of the river itself. To investigate how temperature and oxygen as single and combined stressors affect the survival and physiology of early life stage Chinook salmon, we reared embryos from fertilization to the fry stage under low temperature and high oxygen, low temperature and low oxygen, high temperature and high oxygen, and high temperature and low oxygen. Fish were sampled at four stages during development to test their upper thermal tolerance and low oxygen tolerance, measure growth, and analyze biochemical responses. Fish reared in low temperature or low oxygen developed more slowly than those in high temperature or full oxygen. Embryos reared in low oxygen had significantly reduced hatching success and the multiple stressor treatment with high temperature and low oxygen had greatly reduced hatching success. Acclimation to warm temperature or low oxygen increased thermal tolerance. Acclimation to low oxygen during development increased tolerance to low oxygen, while high temperature reduced low oxygen tolerance. These results demonstrate the importance of water management strategies that consider other abiotic stressors in addition to temperature to promote survival of early life stage Chinook salmon in the Central Valley and further explore the interaction between temperature and oxygen on fish physiology.

55-7 DELANEY, DM*; JANZEN, FJ; Iowa State Univ.; *dmdelane@iastate.edu*

Can Offspring Dispersal Ability Influence Maternal Investment Strategies?

The choice of oviposition site often has strong effects on offspring survival. The risk of predation of nest sites and the proximity of nest sites to suitable offspring habitat can influence this decision. Yet, how offspring dispersal ability might interact with such factors to influence maternal investment strategies is unclear. In aquatic turtles, terrestrial nests laid farther from shore often have higher survival because nest predators (e.g., raccoons) tend to forage along environmental edges. However, offspring from eggs deposited farther inland must migrate a greater distance to water upon emergence from their nests. To explore this tradeoff in light of offspring dispersal ability, we collected and measured the body size of 428 hatchling common snapping turtles (*Chelydra serpentina*) from 15 nests. We released the turtles 25 m, 62.5 m, and 100 m from a drift fence and subsequently monitored survival, time to fence, and orientation during overland dispersal. Not surprisingly, survival decreased with dispersal distance and no selection on body size was evident for hatchlings dispersing from 25 or 62.5 m. However, survival increased with body size for hatchlings dispersing from 100 m. Thus, because larger offspring are less affected by long dispersal distances, females producing large eggs can oviposit farther from water to maximize nest survival while also permitting offspring a reasonable chance to survive overland dispersal. These findings suggest that offspring dispersal ability can be an important factor influencing maternal investment strategies.

41-6 DELIA, J*; WARKENTIN, KM; Boston University, Boston; *jdelia82@gmail.com*

Father-embryo coevolution in Neotropical glassfrogs

The evolution of parent and offspring traits is likely shaped by the social dynamics of family life. Theory has explored how interactions between the sexes impacts variation in parental investment and how such variation favors offspring adaptations. Empirical tests, however, often focus on species with ‘conventional' sex roles, where mothers provide most of the care. Our research examines how interactions between sexes impact the evolution of paternal and embryo behavior in glassfrogs. We conducted field observations of 40 species from across the family tree. Comparative analyses support that male-only care evolved repeatedly from female-only care, in association with extended care durations and changes in egg-clutch structure. These results suggest that male care and offspring need coevolve. Both care duration and hatching timing vary within and among species. Removal experiments in 6 species found that embryos hatch early to escape abandoned eggs and extend development in ovo under prolonged care. Experiments in 5 species reveal that delayed hatching benefits embryos in multiple ways. Across species, evolutionary changes in the magnitude of hatching plasticity are positively associated with extensions in care duration. These co-extensions occur in species where paternal males continue mating and care for several clutches concurrently. We tested whether social conditions affect paternal and embryo behavior by manipulating male mating-rates within 2 independent origins of male care. Males that mated more cared for eggs longer, and embryos delayed hatching. Thus, hatching plasticity allows embryos to exploit socially-driven changes in parenting. This work supports that embryo strategies are evolving in association with parental care, and provides insight on how family life can alter selection on offspring traits even within the egg.

12-6 DELORENZO, L*; IRSCHICK, DJ; BERGMANN, P; WAGNER, G; SILER, C; University of Massachusetts at Amherst, Clark University, Yale University, University of Oklahoma; *irschick@bio.umass.edu*

3D analysis of body elongation of Brachymeles lizards and other taxa

The evolution of limblessness and snakelike forms is a repeated theme in reptilian evolution. Within lizards, the loss of limbs or digits, and the association with a fossorial habitat is a key driver of diversity. However, because of the complex nature of their tubular bodies, quantifying the shapes of lizards with limb loss and reduced or lost limbs is challenging. We focused on the lizard group Brachymeles, which is widespread and diverse in the Philippines. This group is notable for their great variation in the loss of their limbs and digits and also in their degree of axial elongation. We used 3D photogrammetry to create 3D models of various species of Brachymeles lizards of varying sizes and shapes and degrees of limblessness. Our goal was to create new ways of describing their overall variation in body shape using 3D metrics. We used either a single camera or a multi-camera rig to create the 3D models, and then used Capturing reality software to reconstruct the model. Our work shows diverse evolution of body forms and a substantial amount of variation in the overall degree of axial evolution. Our work shows how novel 3D technologies can provide insights into general evolutionary issues.

5-6 DEMARTINI, DG*; MONNIER, CA; WAITE, JH; University of California-Santa Barbara; *demartini@lifesci.ucsb.edu*

Stiff-Balls, Stretchy-Balls, Soggy-Balls? Structure-Function Comparisons of the Protective Coatings on Load-bearing Mussel Threads

One salient feature key to mussel survival is their ability to rapidly create a permanent holdfast known as the byssus, a bundle of threads glued to the substrate. These threads can persist for months despite no cellular maintenance and exposure to high tensile loads, abrasion, desiccation, and bacterial attack. Threads have a collagenous core that is coated by a protective cuticle. The collagenous core is understood to be responsible for the tensile properties of mussel threads, whereas the cuticle is theorized to protect and preserve the load-bearing core. We used transmission electron tomography, atomic force microscopy, along with other techniques to investigate the cuticle ultrastructure and mechanics of several California mussel species (*Mytilus californianus, Mytilus galloprovincialis, Septifer bifurcatus,* and *Modiolus capax*). The cuticle produced by each of these species has a distinct morphology characterized by mesoscale granular inclusions ("balls") embedded in a continuous matrix. We explored potential contributions of the various morphologies, including: arrest of crack propagation, increased wear-resistance, increased extensibility and protection against dehydration. We attempt to reconcile the structural and mechanical properties of the differing cuticles to their unique ecological niches, and thereby gain biological insights into the design of protective coatings.

P1-252 DEMIRCAN, AS*; MEREDITH, TL; PORTER, ME; Florida Atlantic University; *ademircan2013@fau.edu*

Elasmobranch Olfactory Organ Morphology Inspires Physical Models

Elasmobranchs (sharks, skates, and rays) are known for their highly acute olfactory sense. They exhibit wide interspecific variation in their olfactory organ morphology, which has largely been quantified by the number of lamellae the organ houses. Attempts to correlate olfactory organ morphology with ecology and phylogeny have not been explanatory. Recent studies have suggested that the vast variation in olfactory organ morphology may facilitate the flow of water through the nose to deliver odorants to the olfactory epithelia. In this study, we quantify morphological variation in the elasmobranch olfactory organ in multiple species, create physical models inspired by organ morphology, and test the effects of morphology on water flow through the model. We examine organ shape (Fineness ratio), lamellar number, and the spacing between lamellae. Organ fineness ratio (L:W) of hammerhead shark species, which have large laterally expanded cephalofoils, is much greater than other elasmobranch species. The number of lamellae varies by species where some species have more than double, which may impact the surface area available for odor detection. Interlamellar spacing also varied by species, and spacing in some species was 50% larger than others. In general, species with a smaller interlamellar spacing have more lamellae than species with larger interlameller spacing. We expect that fluid dynamics in the model will vary with model morphology. We will build models inspired by organ fineness ratio, number of lamellae, and interlamellar spacing. This data will provide insight on how morphological variation inside elasmobranch noses affects detection of and binding to odorants.

31-1 DEORA, T*; CAMPOS, EO; BRUNTON, B; DANIEL, TL; Department of Biology, Univ. of Washington, Seattle, WA; *tanvid2@uw.edu*

Role of Touch in Shaping Plant-Insect Pollinator Interaction

The coevolution of flowering plants and their insect pollinators has led to rapid diversification in both groups. Plants have evolved species-specific visual and olfactory cues to attract insects and insects use these sensory cues to identify and navigate to a host plant. Although these roles of vision and olfaction underlying plant-pollinator interactions has received much interest, surprisingly little is known about the contribution of mechanosensation in shaping this interaction. By combining behavioral analyses of moths (*Manduca sexta*) feeding from 3D printed flowers along with SEM and X-ray microtomography, we aim to understand how insects extract this tactile information and which mechanosensors contribute to this ecologically relevant behavior. Indeed, recent work has shown that mechanical information is at least as salient as visual information in guiding the ability of moths to track moving flowers, once they are engaged with the nectary. However, before moths even fully engage with a flower, they unfurl their coiled, straw-like proboscis as they approach the flower. Hovering over the flower, the moth probes the surface with its proboscis. Morphological features such as mechanical grooves on the flower could serve as nectary guides. Moreover, floral shape (curvature, size of nectary opening) also profoundly affects feeding performance. However, how moths use tactile cues to find the nectary location and where this mechanosensation occurs remains largely unknown. We used 3D printed flowers of differing morphologies to explore the relationship between floral shape and nectary exploitation. We found that, over repeated trials, moths became increasingly efficient at locating the nectary. Moreover, this process depends on floral morphology. These results point to a capacity of moths to use active exploration in learning the flower shape.

P2-277 DEVER, K; CARR, J; GIRARD, J; CALZARETTE, D; REMSEN, D; GAGE, G; CHUGUNOV, I; WEISSBOURD, B; CORDEIRO, M; MIAO, J; MARVEL-ZUCCOLA, J; NEWSTEIN, P; PERAMBA, K; Marine Biological Laboratory, Woods Hole, MA; EDSINGER, E*; Marine Biological Laboratory, Woods Hole, MA; Marine Biological Laboratory, Woods Hole, MA, Backyard Brains, Ann Arbor, MI, California Institute of Technology, Pasedena, Roger Williams University, Providence, RI, Bowdoin College, Brunswick, MN; *eedsinger@mbl.edu*

Octocams: A simple scalable system for short-term to lifecycle monitoring of behavior in aquaria.

Cephalopod and other marine invertebrate behavior is of growing interest for research but monitoring animals in a culturing environment is a challenge. Our goal is to develop a simple scalable real-time imaging system and downstream computational tools for short to lifecycle experiments on animal behavior in aquaria. Culturing of twenty-one California Two-Spot Octopus, *Octopus bimaculoides*, was done for several months, with continuous data collection. Digital security cameras provided wide-angle views of entire seawater volumes when placed inches above the surface, allowing aquaria to be housed in racks with minimally spaced shelves. Wireless data transmission enabled continuous streaming to the cloud, where data could be viewed and processed, or automatically archived. Near infrared security lighting is invisible to most animals, allowing even illumination and recording of nocturnal activities. Outdoor cameras and lights are waterproof, a critical feature in wet culturing conditions. Python scripts automated quantification of octopus behaviors, including color, contact, and movement. Octocam.io is where the public can follow the project.

44-4 DEVRIES, MS; Scripps Institution of Oceanography, UC San Diego; *mdevries@ucsd.edu*

Leaving room for two at the dinner table: morphology and competition govern the diet breadth of sympatric spearing and smashing stomatopods

Competition for food drives the evolution of specialized feeding morphology. Stomatopod crustaceans are often touted as having highly specialized feeding morphologies that are typically one of two forms: the more ancestral spear-like appendages used to ambush soft-bodied evasive prey ("spearers") or hammer-like appendages that produce extremely high forces used both to break hard-shelled prey and to capture evasive prey ("smashers"). To evaluate associations between appendage type and feeding ecology, the diets of a smasher (*Gonodactylus childi*) and a sympatric spearer (*Raoulserenea moorea*) (size range: 21-27 mm) were compared. Stable isotope analysis and the Bayesian mixing model, MixSIAR, were used to estimate the proportional contributions of different prey to the diet for each species. Models were run with an experimentally-derived discrimination factor (DF; difference between predator and prey isotope values) as well as a DF calculated from the literature. Results from all models showed that both species had wide diets that included hard-shelled and soft-bodied prey, although in different proportions. The smasher consumed mostly hard-shelled prey (68-70%), and the spearer consumed mostly soft-bodied prey (62-73%). These similarly-sized species may produce similar kinematics, allowing them both to capture evasive prey and hammer hard-shelled prey, thereby broadening their diets. Yet, the spearer species is more adept at capturing evasive prey, indicating that small spearers are stronger competitors for soft-bodied prey. These findings suggest that a smasher's ability to access hard prey reduced competition for soft prey, which may have conferred an important benefit favoring the evolution of the impressive smashing strike.

47-4 DEYARMIN, J*; MCCORMLEY, M; CHAMPAGNE, C; STEPHAN , A; HOUSER, D; CROCKER, D; KHUDYAKOV, J; Univ. of the Pacific, Nat. Marine Mammal Foundation; Old Dominion Univ., Dept. of Biological Sciences, Nat. Marine Mammal Foundation, Sonoma State Univ.; *j_deyarmin@u.pacific.edu*

Stress-omics: A non-targeted multi-omics approach to discriminate stress states in a marine mammal

Repeated or chronic stress, such as that caused by anthropogenic activity and environmental disturbance, can affect animal health and fitness and contribute to population declines. However, the physiological impacts of repeated stress have not been extensively studied in wild animals, hindering development of biomarkers that conservation practitioners can use to identify chronically stressed individuals. Baseline endocrine measurements are commonly used for stress diagnosis, but they may be less robust indicators of stress than their downstream molecular mediators. We used a non-targeted, multi-omics approach to profile global changes in target gene and protein abundance in response to acute and repeated stress in a marine mammal study system, the northern elephant seal *(Mirounga asgustirostris)*. We simulated chronic stress by administering adrenocorticotropic hormone (ACTH) to juvenile seals once daily for four days and collected blubber before and after the first ("acute") and last ("chronic") stress challenges. We then sequenced the blubber transcriptomes and proteomes using Illumina RNA sequencing and liquid chromatography tandem mass spectrometry, respectively. We developed computational pipelines to compare transcript and protein expression between stress states and identify cellular consequences and unique molecular markers of repeated stress in a marine mammal. These included factors that affect energy balance and other cell maintenance pathways in response to repeated stress. The stress markers identified in this study may be used to assess stress states in vulnerable marine mammal populations using targeted assays.

133-1 DI SANTO, V.; Harvard University;
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Ocean Acidification and Warming Affect Cartilage Mineralization in Little Skate Leucoraja erinacea
Quantifying the combined effect of increasing ocean temperature and acidification on performance and morphology of fishes is key to improving our understanding of how species will respond to global climate change. Elevated CO_2 and temperature are known to increase stress and decrease metabolic performance in teleosts and elasmobranchs. There are currently no data on the combined effect of ocean acidification and warming on elasmobranch cartilage mineralization. Here, I developmentally acclimatized little skate *Leucoraja erinacea* embryos to current and increased temperature and CO_2 conditions as expected by year 2100 (15 and 20 °C, 400 and 1100 µatm, respectively), in a fully crossed experimental design. Using micro-CT, I compared density and size of jaws, crura, vertebrae and pectoral fins cartilage of juvenile little skate. Both warming and CO_2 increased cartilage mineralization in little skate. Higher mineralization increases stiffness and strength of skeletal elements with implications for feeding and locomotion. These results are in sharp contrast with previous work on adult elasmobranchs which notes no significant effect of CO_2 or temperature on skeletal elements. This study demonstrates the importance of quantifying the response of organisms to climate-related stressors after long-term developmental acclimatization, if the objective is to forecast more realistic outcomes.

P2-181 DIAMOND, KM*; SCHOENFUSS, HL; BLOB, RW; Clemson Univ., St. Cloud State Univ.; *kmdiamo@clemson.edu*
Do the best come first? Locomotor performance over the course of migration events in the amphidromous goby fish, Sicyopterus stimpsoni
As migratory animals move between environments, changes in selection pressures may impede their chance of success. However, in mass migrations, individuals that encounter these pressures at different times might differ in performance, and pressures may change in intensity. How closely matched are migrator performance and selection intensity through time? The life cycle of the Hawaiian goby, *Sicyopterus stimpsoni*, requires juveniles to migrate from marine, larval habitats to upstream, freshwater adult habitats. During migration, these fish face two major selection pressures: piscivorous predators, and waterfalls that block upstream reaches. Both pressures might decrease in intensity through time, as predators might become satiated later in migrations, and the flash flood pulses that stimulate migrations should decrease in strength, reducing the flow against which fish must climb. We tested whether the earliest fish to arrive during migrations might have the highest performance, enabling them to succeed against pressures at their greatest intensity. To test these predictions, we collected migrating juveniles each day for days 2 through 7 post-flood, and conducted both escape performance and climbing trials each day to compare performance across fish entering the stream at different times in the migration event. Our results showed that escape performance remained uniformly high throughout our sampling period, but that climbing performance peaked 5 days after the flooding event before again declining. These data indicate that early migrants are not necessarily the strongest individuals, and could improve understanding of how diverse morphologies and behaviors are maintained in upstream populations despite the strong selection imposed on these fish.

P3-257 DIAZ, MI*; SMITH, RJ; SHUMAN-GOODIER, M; SINGELTON, GR; ALMAZAN, L; PROPPER, CR; HADI, B; Northern Arizona University, International Rice Research Institute; *mid28@nau.edu*
Amphibians as Ecosystem Service Providers in Filipino Rice Fields
Pesticide usage in rice fields has surged since the early 1970's in the Philippines to help meet the food needs of a rapidly growing population. An increased exposure to pesticides can lead to health problems in humans and compromise various life history traits of organisms in the surrounding environment. Rice fields provide habitat to many amphibian species that may provide pest control services that could lead to reduced pesticide use. We evaluated food consumption of *Rhinella marina* (invasive species) and *Fejervarya vittigera* (native species) to determine whether amphibians provide potential to control insect pests in rice fields. Standard transects were conducted on 12 nights. We collected 34 *F. vittigera* and 63 *R. marina* and flushed their stomach contents; complete or partially digested insects were collected. All organisms were identified to order and classified as rice pest, non-rice pest, predator, scavenger, or parasitoid. *R. marina* ate a significantly greater numbers of individual food items compared to *F. vittigera*, but there was no difference in the total mass of their food items. *F. vittigera* ate more pest species of rice, *R. marina* ate more predatory species. Hence the invasive toad may not provide the same level of ecosystem services for pest control as the native *F. vittigera* since it ate fewer pest items and more rice pest predators. Future research needs to quantify whether actions to increase the density of native frog populations of *F. vittigera* can moderate high insecticide use in rice fields.

141-1 DICK, MF*; WELCH, KC; University of Toronto, Scarborough; *morag.dick@utoronto.ca*
Oxidation of dietary sugars in ruby-throated hummingbirds
Nectar feeding animals, such as hummingbirds, have some of the highest metabolic rates measured to date. Hummingbirds have the capacity to completely fuel hovering flight with recently ingested sugars to meet these high energy demands. Even more remarkable, hummingbirds have the ability to oxidize either fructose or glucose at rates high enough to support hovering. This suggests direct oxidation of fructose in the flight muscle is occurring without prior metabolism. This is in contrast to traditional mammalian models were the use of recently ingested sugars is limited, and fructose is not directly metabolized in skeletal muscle. The ability of hummingbirds to achieve high oxidation rates is reflected in adaptations enabling high rates of sugar absorption, transport and oxidation in the flight muscles. Within the flight muscle, there is a high capacity to transport and phosphorylate both glucose and fructose. Although the metabolic pathways enabling fructose oxidation have yet to be characterized in the flight muscle, the pentose phosphate pathway is strong candidate. Using a combined respirometry and stable isotope approach, we examined hexose preference and the involvement of the pentose phosphate pathway in sugar oxidation in ruby-throated hummingbirds (*Archilochus colubris*). We predict that pentose phosphate pathway enables high fructose oxidation rates in the flight muscle, however when both glucose and fructose are available glucose will be the preferred substrate.

10-4 DICKERSON, BH*; HUDA, A; DICKINSON, MH; California Institute of Technology; *bdicker@caltech.edu*

Visually-mediated control of Drosophila haltere kinematics modulates mechanosensory input

Gaze stabilization relies upon the detection of self-motion cues, which are subsequently suppressed for active gaze shifts. Yet, it is poorly understood how animals lacking standard vestibular systems, such as flying insects, discriminate self-motion from external body rotations. Flies are unique among this group of organisms as they possess organs that operate in part as vestibular sensors known as halteres. Evolutionarily derived from the hindwings, the halteres provide mechansensory feedback to structure the wingstroke. However, the potential for the haltere to serve as more than a passive sensor to initiate or control maneuvers remains unclear. The haltere possesses tiny steering muscles that are serially homologous to those of the forewings that receive visual input. Thus, haltere reflex circuits may be co-opted during voluntary maneuvers. We tested the capacity for the visual system to modulate mechanosensory input by expressing the genetically-encoded calcium indicator GCaMP6f in the haltere afferents and steering muscles of the fruit fly, *Drosophila melanogaster*. Adapting preparations to image calcium activity from the muscles or brain of Drosophila with epifluorescent or 2-photon microscopy, we simultaneously recorded flies' behavioral responses to visual motion stimuli in tethered flight. We show that mechanosensory feedback from the halteres is modulated by visual feedback for both gaze stabilization and redirection maneuvers. This modulation is the result of changes to the haltere's kinematics, through the visual system's connection to the haltere's steering muscles. Our results point to a mechanism by which flies can modify hard-wired flight reflexes to produce voluntary behaviors.

P3-188 DICKSON, K*; ESTESS, E; FARWELL, C; FORSGREN, K; FUJIOKA, K; KITAGAWA, T; MALIK, A; SCHULLER, K; California State Univ. Fullerton, Monterey Bay Aquarium, National Research Inst. of Far Seas Fisheries, Shizuoka, Japan, Univ. Tokyo, Kashiwa, Japan, Flinders Univ., Adelaide, South Australia; *kdickson@fullerton.edu*

Ontogenetic Changes in the Counter-Current Heat Exchangers Required to Elevate Slow-Oxidative Muscle and Visceral Temperatures in Pacific Bluefin Tuna, Thunnus orientalis

In Pacific bluefin tuna, vascular counter-current heat exchangers composed of numerous parallel arterioles and venules conserve metabolic heat, allowing temperatures of the slow-oxidative (red) locomotor muscle and visceral organs to be elevated above water temperature (= regional endothermy). We used a thermocouple thermometer to measure maximal tissue temperatures immediately after capture in juvenile Pacific bluefin tuna specimens ranging in size from 18.4 to 62.5 cm fork length (FL), encompassing the size range over which the capacity for regional endothermy develops. We quantified the amount and distribution of the red muscle in frozen, sectioned, whole individuals, and examined the counter-current heat exchangers using standard paraffin histology. The temperature of the red muscle and the viscera were elevated significantly above ambient water temperature in individuals $\geq$ 33.3 cm and 59.7 cm FL, respectively. The amount of red muscle increased isometrically with fish mass. Red muscle was contiguous with the skin in the smallest individuals, but in larger individuals white muscle fibers were positioned between the skin and the red muscle. The number of blood vessels within the heat exchangers increased with fish size. Increases in both the mass of tissues that produce heat and the size of the counter-current heat exchangers that retain heat contribute to the transition to regional endothermy in the Pacific bluefin tuna.

43-7 DILLON, ME*; OYEN, KJ; PIMSLER, ML; HERNDON, JD; STRANGE, JP; LOZIER, JD; Univ. of Wyoming, Univ. of Alabama, Utah State Univ., Univ. of Alabama; *Michael.Dillon@uwyo.edu*

Geographic variation in bumble bee morphology: evidence for the influence of heterothermy and flight on insect size clines

Body size clines and their underlying drivers have long fascinated ecologists. After finding consistent increases in body size with latitude among endothermic species, Bergmann posited that the pattern was driven by heat conservation (larger organisms have relatively less surface area). This ecological rule has since been extended to non-endotherms and to intraspecific comparisons. Insects show both increases and decreases in size across latitude and altitude, with multiple explanations proposed for these contrasting patterns. As ectotherms, heat loss may not be the primary selective mechanism; instead, the temperature size rule, seasonal constraints on development time, and reproductive and energetic benefits of large body size may more strongly determine geographic variation in morphology. Heterothermic bumble bees (genus *Bombus*) are broadly distributed across latitude and altitude and develop in temperature-regulated nests, making them a unique intermediate test case for insect size clines. We measured geographic variation in body and wing morphology of two bumble bee species (*Bombus vosnesenskii* and *Bombus bifarius*) collected across multiple years and seasons from 36 to 48 °N latitude and from sea level to over 2900 m in elevation (>1700 individuals at 115 sites). *B. vosnesenskii* is broadly distributed but less common at higher elevations whereas *B. bifarius* is found only at mid to high elevations. Comparisons of inter- and intraspecific variation in morphology across latitude and altitude suggest that facultative endothermy may diminish the importance of heat conservation in driving size clines, that reduced air density at altitude may impose aerodynamic constraints on body size, and that climatic niche may alter clinal morphological variation.

P2-204 DIMITROV, MA*; BLOCK, BA; Stanford University; *marinadi@stanford.edu*

The Biomechanical Role of Tunas' Unique Bony Peduncular Keel and Great Lateral Tendon in Thunniform Locomotion

We compared the internal force-generating structures of tunas and other pelagic predatory fish, identifying key biomechanical adaptations that characterize thunniform swimming. In particular, we describe the role of the bony peduncular keel unique to tunas as a guide for the great lateral tendon (GLT), increasing mechanical advantage of the associated muscle myomeres and improving efficiency of the tail stroke. In tunas, centralized red muscle enables endothermy and powers cruising. Without the keel, this muscle would have a poor angle with low mechanical advantage to move the tail. Mechanical advantage is related to the angle of the force applied - the closer to perpendicular, the greater the torque produced by an equal force. For this case study, we developed a novel dissection approach to measure the GLT incidence angle in 3 skipjack tuna (*Katsuwonus pelamis*), 4 yellowfin tuna (*Thunnus albacares*), and 4 bluefin tuna (*Thunnus thynnus*). In the skipjack, this angle increased with curved fork length (13 to 19 deg). This may indicate that as a skipjack grows, swimming efficiency becomes more valuable than speed. At a similar length, skipjack had a smaller angle than yellowfin and bluefin, which may imply yellowfin and bluefin are more tuned for speed than skipjack. Yellowfin and bluefin maintained a fairly constant angle (around 14 deg) for fork lengths of 70 to 180 cm. These internal structures that power the caudal fin and peduncle in tunas can be connected to the motion observed in *in situ* video from a camera tag, or from overhead in a flume. By understanding how tunas actuate their main propulsive foil, we can look to future applications in bio-informed robotics by identifying key features that drive thunniform locomotion.

5-5 DITSCHE, P.*; GERGILEWICH, E,; LIANG, T.; WILGA, C.; University of Alaska Anchorage; *pditsche@alaska.edu*

Big Skate (Raja binoculata): Crushing hard prey with cartilaginous jaws - What impact does shape have?

Raja binoculata, the largest skate species of North America, inhabits the ocean bottom from the marine intertidal to the continental shelf, where it feeds on shellfish, worms and crabs. For crushing hard shelled prey the teeth of big skates need to be well supported by the jaws. The jaw suspension is euhyostylic, which means that the upper jaws are not directly connected to the cranium giving them more freedom of movement, and the hyoid is broken up. Moreover, the jaws are composed of tessellated cartilage, which inspired us to look closer at its biomechanical properties. In this study, we used mechanical testing (E-modulus, flexural stiffness, strength), microscopical methods in combination with specialized calculations (minaralization, second moment of area), 3D scanning and 3D printing to investigate how R. binoculata crushes hard shelled prey. Our results for the second momet of area and flexural stiffness show that the shape of the jaws is strongly optimized to withstand crushing forces. In addition to quantifying compressive strength, strain and E-Modulus of the jaw elements of R. binoculata, we investigated the effect of the irregular shape of the cartilage elements on the mechancial variables. In contrast to engineered shapes, biological shapes are not standardized along geometric paramenters and as composite materials can not be modified into one for testing. Nevertheless, biologists use the same methods to measure biomechanical parameters to assess the performance of biological shapes. Using 3D-prints of synthetic material similar to cartilage, with the same shape as the jaw elements, we found that shape can impact the measured values of biomechanical properties.

P3-148 DITSCHE, P.*; HOFFMANN, F; KAEHLERT, S; KESEL, A.; GORB, S.; University of Alaska Anchorage, University of Applied Science Bremen, University of Kiel, University of Kiel; *pditsche@alaska.edu*

"Spoiler"-legs help stream mayfly larvae to stay on the ground

While a life in running water guaranties a constant supply with food, nutrients and oxygen, the physical features of this current shaped environment can be challenging. Stream insects have developed both, behavioral and morphological strategies to deal with flow forces. The mayfly larva Ecdyonurus sp. crawls to current exposed places to graze on algae on top of stones. Their dorso-ventrally flattened body shape is often considered to be an adaptation to flow forces. However, while this shape reduces drag, the same body shape increases lift. The later puts the larvae in danger of being detached from the bottom substrate. We used microscopic techniques, 3D-printing, and force measurements in a wind tunnel to investigate the role of the widened femora of Ecdyonurus sp. larvae in counterbalancing these lift forces. Our results show that the larvae use their femora like spoilers generating a downwards directed force (negative lift), which helps them to stay on the ground. The larva can actively regulate the amount of lift by changing the femur's angle of attack. Depending on the specific conditions these stream insects can even use the ground effect to support the generation of negative lift.

P3-199 DIVITO, KR*; JUE, NK; TRUSIAK, S; OBERGFELL, C; BUCKLIN, A; O'NEILL, RJ; DIVITO, Kate; UConn, UConn, California State University; *kate.divito@uconn.edu*

Bloom or Bust: Genomic analysis of Salpa thompsoni in a rapidly changing environment

Rapid warming of the Southern Ocean has impacted global distribution and abundance of many key marine zooplankton, including the Antarctic Salp, *Salpa thompsoni*. Although frequently overlooked, *Salpa thompsoni* is a highly efficient filter feeder that has exceptional capacity for rapid population growth - bloom formation - as the Southern Ocean warms. These blooms significantly reduce primary production and availability of phytoplankton for other primary consumers causing major alterations of the pelagic food web. While it is clear that salps form blooms when environmental conditions are favorable, the genetic mechanisms of their complex life history that facilitate successful salp bloom formation in response to changing ocean temperatures are currently unknown. Therefore, we aim to understand and predict the ability of *Salpa thompsoni* to adapt to environmental variability and alter their biogeographic distribution and abundance through bloom cycles. Our previous work uncovered that *Salpa thompsoni* genomes, like those of other tunicates, are evolving at higher rates than other chordates. Further research will focus on completion of a comprehensive reference genome for the Antarctic salp to aid in the identification of genes and gene networks that may be subject to positive selection (i.e. evolving at elevated rates) and show differential response to environmental changes. Additionally, we will look at novel small RNAs that reflect unique regulatory mechanisms and developmental processes. Completion of a reference *Salpa thompsoni* genome assembly will provide a valuable foundational resource for researchers seeking to understand the dynamics of the Southern Ocean pelagic food web and potential responses of this ecosystem to climate change.

20-2 DIXON, GB; KENKEL, CD*; Univ. of Texas, Austin, Univ. of So. California; *ckenkel@usc.edu*

Investigating genes involved in the evolution of coral reproductive and symbiont transmission modes

Reef-building corals exhibit substantial variation in their reproductive biology. Most corals mass spawn gametes, yet some taxa exhibit internal fertilization, releasing fully developed planula larvae, in the process known as ‘brooding'. Most corals acquire symbionts from their environment each generation in the process known as ‘horizontal' transmission, but some species employ ‘vertical transmission', and are capable of passing symbionts directly to their offspring. In addition to mining publicly available genomic resources, we sequenced a set of coral transcriptomes for species representing a variety of reproductive and symbiont transmission modes and used a comparative genomics approach to identify genes showing repeated signatures of non-neutral mutation rates in brooding and vertically transmitting lineages. Contigs for each transcriptome were converted into candidate protein coding sequences and 6,625 orthologs were inferred using the program FastOrtho in combination with a reciprocal best BLAST match. To identify genes showing differential signatures of selection, dN/dS ratios were calculated by comparing species exhibiting target traits (brooding or vertical transmission) with their closest divergent-trait relative (broadcast spawning or horizontal transmission). Purifying selection (i.e. dN/dS ratios<1) was more prevalent than positive selection (dN/dS ratios>1), but preliminary results highlight candidate genes involved in the process of cilium assembly as being highly conserved among coral species exhibiting transovarial vertical transmission of symbionts.

P3-187 DOBKOWSKI, KA*; KOBELT, J; CROFTS, SB; DETHIER, MN; University of Washington/Friday Harbor Labs, Montclair State University, University of Illinois - Urbana-Champaign; *kdobkows@uw.edu*
Juvenile Clam Failure Across Ontogeny
Top-down control by consumers helps regulate prey populations and thereby structure communities. Small shore crabs (genus *Hemigrapsus*), usually not considered to be significant predators, may contribute to very high field mortality of newly settled clam spat before the baby bivalves achieve a size refuge from crushing. We used a Materials Testing System (MTS) to compare the peak load (N) required for crushing (shell failure) of small clams of different species, including Manila (*Venerupis*), softshell (*Mya*), and the invasive Varnish (*Nuttallia*) clams, across an ontogenetic range of sizes (2 to 19 mm length). For each individual clam, we measured shell length, width, and thickness and recorded the peak load (N) at which the shell failed. We also compared the effects on crushing force required for clams grown for a year in the field with and without oyster shell pieces added to the sediment to locally buffer pH. We found that the peak load vs. length scaled allometrically for Varnish and Manila clams, and isometrically for softshell clams. The force required for crushing (indicated by the intercept of the allometric line) also varied among the clam species. We also looked at morphological scaling of shell thickness vs. length and found the scaling to be similar among species. We did not find a difference in the scaling relationship for clams grown with and without added shell but we did find a difference in force to fail, with control clams grown in plain sediment withstanding more force, contrary to what would be expected if there was a pH buffering effect of shell addition. These results, when combined with *Hemigrapsus* feeding trials, will provide a better understanding of size refugia for very small clams and of predator-prey interactions across ontogeny.

135-4 DOMINGUEZ, SA*; RYAN, DS; NIGAM, N; WAKELING, JM; Simon Fraser University, Burnaby, BC; *domingue@sfu.ca*
Unsteady Nonlinear Elasticity Modelling Skeletal Muscle in 3D
In this presentation we introduce a fully dynamic model to describe cyclical contraction of skeletal muscle as a 3D tissue using the finite element method (FEM). As a point to start, a quasi-static model was developed to answer some basic questions about the force output as a function of the length of fibres in muscles, their curvature and deformation during contraction. We considered three different tissues: muscle, tendon and aponeurosis. In addition to these tissues, we also considered a base material (or base component). This material captures the mechanical properties of other tissues and fluids within and surrounding the fibres. This previous model does not include velocity, acceleration and mass and so this features were implemented into the fully 3D dynamic model. Now this allows the work-loop behaviour to be determined for the whole muscle contractions.

134-2 DONATELLI, CM*; PORTER, ME; SUMMERS, AP; TYTELL, ED; Tufts University, Florida Atlantic University, University of Washington; *cassandra.donatelli@gmail.com*
The relationship of vertebral column morphology to body mechanics and 3D kinematics of elongate fishes.
The elongate fish body form and anguilliform swimming mode evolved many times across taxa, suggesting a benefit from combining the two. In addition to the well studied 2D bending wave, some elongate fish twist about the long axis, producing a 3D wave of motion. Despite similar body plans and 2D swimming mode, the 3D wave varies across species. Some characteristics of vertebral anatomy may dictate parameters of the 3D wave. We compared vertebral structure to swimming behavior in eight elongate fish species. Using CT scans, we measured parameters including centra angle and diameter along the body. We found that centra angle is deep anteriorly (70-85 deg) and shallow posteriorly (50-65 deg) for all species. Centra diameter is large at the head (0.009-0.013 BL) and small at the tail (0.005-0.007) for most species. We then used 3D printed parts (vertebrae) and cast polymer (intervertebral joint) to construct physical models based on these measurements. Models were bent and twisted on a material testing system to determine effect of morphology on stiffness of the joints. Centra diameter is the best predictor of stiffness with larger diameters requiring less force to deform. We compared these data to mechanical tests done on fish and found that morphology may play a role in the mechanics of some species but not others. For example, the Penpoint Gunnel has a relatively constant centra diameter (0.0085 BL) from head to tail, and torsional stiffness is also constant (0.0005 Nm/rad). In contrast, the Black Prickleback has one of the largest decreasing gradients in centra diameter (0.012 - 0.008 BL) down the body, yet torsional stiffness still remains relatively constant (0.0005 Nm/rad). There is no clear trend between vertebral morphology and 3D kinematics, which may suggest an alternative mechanism for 3D control.

63-6 DONG, E M *; ALLISON, W T; University of Alberta; *edong@ualberta.ca*
Exploring the Evolutionary Origins of Vertebrate Vision in the Degenerating Eye of Pacific Hagfish.
The eye is a precise and complex organ which has remained remarkably conserved despite changes in morphology as vertebrate lineages adapted to diverging life histories. The same distinguishing eye characteristics found in humans are also found in zebrafish and lamprey, implying that our eye (as it first arose) has remained nearly unchanged since at least the time that lamprey diverged, nearly 500 million years ago. Though development and structure have been well defined across vertebrates, our understanding of how the eye evolved remains poorly understood. Pacific hagfish (*Eptatretus stoutii*) are in the unique position of straddling the boundary between eyed vertebrates and non-eyed chordates. Likewise, their eyes are difficult to categorize as they lack many of the diagnostic features shared by vertebrates including a lens, ocular musculature, and a 3-layered retina. These relatively simple features lead us to question: is the hagfish eye representative of a transitional species in the evolution of vertebrate eyes, or is it degenerate? We hypothesize that the lack of observable vertebrate-like organization in the adult hagfish retina may be due to a degeneration or re-distribution of retinal cell types during maturation and growth. Preliminary evidence suggests that juvenile hagfish show layering of the retina that more closely resembles that of vertebrates in comparison with adults. Using RNAseq, protein and gene expression assays, this project aims to further explore retinal cell-types and their organization within the hagfish retina in order to better interpret their morphology in the greater context of vertebrate eye evolution. We will capture any characters that aid us in revealing the hagfish eye as degenerate or ancestral, allowing us to place the hagfish in the context of the evolution of the vertebrate eye.

63-5 DONOHUE, MW*; COHEN, J; VALDEZ-LOPEZ, JC; CRONIN, TW; University of Maryland Baltimore County, University of Delaware; *willard3@umbc.edu*

A Lesson from the Mind's 'Eye': Cerebral Photoreception in Mantis Shrimp

The uncommonly complex eyes of stomatopod crustaceans, or mantis shrimp, feature unique anatomical and physiological features that are thought to illustrate visual adaptations. Gonodactyloid mantis shrimp eyes have six equatorial midband rows and four spectral types of filters to detect the variety of light stimuli in their shallow coral reef habitats. On the other hand, most squilloid mantis shrimp are associated with darker light environments, have only two midband rows, and lack filters altogether. In addition to their unique anatomical specializations, mantis shrimp eyes contain the largest diversity of light-sensitive visual pigments known for animals. We now describe a photosensitive ventral eye associated with the cerebral ganglion, or brain, in a gonodactyloid mantis shrimp (*Neogonodactylus oerstedii*), which is the first direct evidence of extraocular photoreception in mantis shrimp. In this gonodactyloid, transcripts that could encode middle- and long-wavelength-sensitive opsins (the protein component of visual pigments) are expressed in the ventral eye and in several additional neuropils, where they may be involved in circadian photoentrainment, shelter-seeking behaviors, multisensory integration, or other functions. In a squilloid mantis shrimp (*Squilla empusa*), we also observe a well-defined ventral eye and several extra-retinally expressed opsin transcripts, suggesting that mantis shrimps inhabiting different light environments and with differing eye complexities are similarly equipped with extraocular photoreceptors.

124-7 DOUGAN, KE*; RODRIGUEZ-LANETTY, M; Florida International University; *katherine.e.dougan@gmail.com*

Comparative Transcriptomics Reveals Extensive Diversity of Insulin-like Peptides in Corals

Insulin is an evolutionarily important hormone with diverse roles in metabolism, cellular growth, development, and longevity in metazoans. While the pleiotropic roles of the insulin pathway are believed to have evolved early on within Metazoa, little is known about its structure and function in non-bilaterians. Putative insulin-like peptides and their corresponding receptors have been identified in just a few species of the non-bilaterian phyla Placozoa, Ctenophora, Porifera, and Cnidaria. However, the potential function of the insulin pathway in symbiosis regulation and/or stress response are of particular significance in Cnidarians due to the economic and ecological importance of reef-building corals. We performed a comparative transcriptomics analysis on 90 Cnidarian transcriptomes including 64 Anthozoan, 15 Hydrozoan, 5 Scyphozoan, 3 Cubozoan, and 3 Myxosporean transcriptomes. A further 37 of the 64 Anthozoan transcriptomes were from the class Scleractinia, which encompasses the major reef-building corals. We investigate the phylogenetic placement of the identified Cnidarian insulin-like peptides and their receptors within Metazoa. Further, we characterize their structure and evaluate their diversity throughout the different Classes within Cnidaria. This study greatly expands our understanding of not only the prevalence but also the diversity of insulin-like peptides and their receptor within Cnidaria.

3-4 DOUGHERTY, LF*; LI, J; BROECKLING, CD; University of Colorado, Boulder, Colorado State University, Fort Collins; *lindsey.dougherty@colorado.edu*

Chemical defenses in the bivalve family Limidae

One of the driving forces of marine biodiversity is predation pressure. The marine bivalve family Limidae is an ideal study system to address this topic. Members of this family have evolved numerous means of predator defenses, including aposematism (warning coloration), flashing displays, tentacle autotomy, and escape swimming. To further characterize defense mechanisms in this family, chemical defenses in the genus *Ctenoides* were examined through behavioral studies and metabolomics. Potential predators of *Ctenoides* were exposed to external (tentacles, mantle) and internal (adductor muscles) bivalve tissues to conduct food choice trials. Predators actively avoided external tissues, including removing them from burrows. Comparative metabolomics analysis was conducted using reverse phase ultra-high pressure liquid chromatography (UHPLC) coupled to time of flight (TOF) mass spectrometry (MS) to evaluate chemical compounds present in potentially distasteful tissues versus edible tissues. The analysis revealed that distasteful and edible tissues have significantly different chemical compositions. Over 1400 chemical compounds were detected in the two types of bivalve tissues, among which nearly 600 have significantly higher concentrations in distasteful tissues. These compounds included many peptides, which may potentially be responsible for the chemical defenses in *Ctenoides*. Future work also aims to utilize comparative phylogenetics to develop a complete understanding of the evolution of defenses within Limidae.

87-4 DOW, EG*; RODRIGUEZ-LANETTY, M; Florida International University; *edow002@fiu.edu*

A CNIDARIAN-SPECIFIC IONOTROPIC GLUTAMATE RECEPTOR LINEAGE FUNCTIONAL IMMUNE RESPONSE

Cnidarians perceive their environment and respond through the innate immune system by recognizing ligands and molecular patterns that send signals to trigger immune physiological responses. Transcriptional evidence underlying immune priming by recurrent bacterial challenges within the anemone, *Exaiptasia pallida*, identified an ionotropic glutamate receptor (iGluR) as a highly up-regulated protein among immune challenged anemones. iGluRs are transmembrane ion channels involved in chemo-sensing and in plants implicated in sensing pathogen- and damage-associated molecular patterns (PAMPs, DAMPs) that act together for hosts to differentiate pathogenic-damaging microbes from beneficial or harmless microbes. *E. pallida* iGluR ligand-binding domain indicates these iGluRs are not specific to classical synaptic-involved NMDA, kainate, or AMPA ligands. Those findings support the hypothesis that *E. pallida* iGluRs belong to a cnidarian-specific expansion within the phylogeny of iGluRs, and retained molecular characteristics to respond to chemical stimuli. Based on this, we postulate that iGluRs may mediate PAMP-triggered immunity via calcium channels by pattern-recognition particles. We tested this hypothesis by measuring iGluR expression response profiles to sub-lethal bacterial challenges. Challenging *E. pallida* anemones with the bacterium *V. coralliilyticus* had a more significant affect on expression patterns than *S. marcescens*. Some iGluRs displayed cyclic gene expression profiles, which has prompted further exploration into diel rhythmicity of expression of cnidarian chemosensory genes. Previous studies have shown a good number of genes in cnidarians seem to be regulated under circadian rhythm. These findings provide further functional analysis to understand the role of cnidarian iGluRs.

112-4 DRAKE, JL*; WHITELEGGE, JP; JACOBS, DK; University of California, Los Angeles; *jeanadrake@eeb.ucla.edu*

Using data mining and mass spectrometry sequencing to derive a consensus coral 'biomineralization toolkit'

Stony coral skeletal proteins, termed the 'biomineralization toolkit', control mineral formation and modify the mineralization milieu. To date, three coral skeletal proteomes have been sequenced, but genomic and transcriptomic data are available for many more coral species. In this study, we used a publicly available comprehensive protein reference database derived from genomic and transcriptomic data from 25 Cnidaria, including 20 stony, to understand the evolution of coral skeletal proteins. We supplemented this with recently published databases focusing on individual protein families. We also used liquid chromatography tandem mass spectrometry (LC-MS/MS) to sequence skeletal proteins from three stony corals obtained from the Natural History Museum of Los Angeles, *Fungia scutaria*, *Pocillopora damicornis*, and *Porites lobata*. Our phylogenetic analysis of publically available coral skeletal protein sequences suggests that one of the three classes of highly acidic skeletal proteins, SAARP2-like, evolved in complex corals after the robust-complex split ~240 Ma. In contrast, the highly acidic CARP4/SAARP1-like and acidic SOMP-like proteins are found across Scleractinia. We also show that, although corals produce many kinds of cadherins, only one, a type-III classical cadherin, is retained in coral skeleton. Finally, our *in silico* analysis reveals that skeletal carbonic anhydrase is quite divergent among corals. Our skeletal protein sequencing supports our phylogenetic analyses and doubles the Scleractinian genera from which such sequences have been determined. As a complete unit, our study reveals both where the 'biomineralization toolkit' shows consensus across Scleractinia and where clades have evolved alternative proteins.

P2-255 DRISCOLL, RMH*; HURD, PL; RENN, SCP; Reed College, Portland OR, Univ. Alberta, Edmonton, AB, CA; *rosdrisc@reed.edu*

Evidence for differential aromatase gene promoter methylation in a cichlid with pH-influenced sex determination

The sex determination mechanism of most species has evolved to maintain a 50:50 sex ratio, but an even mix of males and females in every brood is not required. The Charnov-Bull model predicts that environmental sex determination should be selected for when early life environmental conditions differentially impact males and females. In the African cichlid fish *Pelvicachromis pulcher*, sex determination is influenced by water pH during the first 30 days of life, producing a male bias at lower (acidic) pH and a female bias at neutral pH. pH also impacts ratios of the two common male morphs, which differ in color and reproductive behavior. Methylation of the gonadal aromatase gene (cyp19a1A) has been linked with temperature sex determination in other teleost species, but has not previously been investigated as a mechanism for pH dependent sex determination. We report that methylation of the cyp19a1A promoter differs between fish raised in acidic and neutral conditions, consistent with a role in pH sex determination. In addition, we report on tissue-specific methylation exhibited by the cyp19a1A gene promoter as well as the brain aromatase (cyp19a1B) gene promoter.

P3-202 DRUPA, SA*; LORDAN, EJ; Loudoun County High School; *smith@burkinc.com*

Hot Bog: The adaptation of Daphnia magna to near-lethal temperatures

Over the next century, the global temperature could rise by 0.2 to 4.3°C, warming oceans and putting many species at risk. *Daphnia magna* is a branchiopod crustacean in the order Cladocera and is commonly known as the water flea It lives in ponds and lakes over a wide range of temperatures (19-33°C). In this experiment, we are testing the upper lethal temperature tolerance of *D. magna* in cultures by subjecting them to near-lethal temperatures (32°C) for a period of 12 hours using an incubator. This promotes sexual reproduction, then we allow the culture to return to 22ºC over a period of an hour and remain so for 34 hours. During this period, the fertilized eggs hatch. The eggs hatch much more slowly in near-lethal temperatures and are far more likely to die quickly after hatching, so a period of rest was necessary to promote growth. During the next cycle of near-lethal temperatures these juvenile *D. magna* will be exposed to the same near-lethal temperatures. We randomly selected five groups of five *D. magna* from the original culture and each group was subjected to the same experiment as above. We subjected separate groups of *D. magna* to varying lengths with one day, three days, five days, one week, and two weeks of this cycle between 32º-22ºC. At the end of the experiment, *D. magna* was tested in water temperatures that had been lethal to the group with no acclimation. Once all *D. magna* were immotile the temperature was held steady. If all *D. magna* remained immotile for 30 minutes, the temperature was recorded as the lethal temperature. Over the course of the experiment, we found that the amount of time allowed for acclimation had no effect on the lethal temperature tolerance of the *Daphnia magna* In the future, we would like to test a much longer period of acclimation to produce a more realistic pressure on the water fleas.

99-1 DUBACK, VE; THOMAS, RI; HUYCK, TL; MBARANI, IM; BERNIER, KR; COOK, GM; PANKEY, MS; WATSON, WH; NEWCOMB, JM*; University of New Hampshire, New England College; *jnewcomb@nec.edu*

Localization and Expression of Circadian Clock Transcripts in the Brain of the Nudibranch Melibe leonina

The nudibranch, *Melibe leonina*, expresses a circadian rhythm of locomotion, and we recently determined the sequence of multiple circadian clock transcripts that may play a role in controlling these daily patterns of behavior. In this study, we used this information to help us: 1) identify putative clock neurons using fluorescent *in situ* hybridization (FISH); and 2) determine if there is daily expression of clock transcripts in the *Melibe* brain using quantitative PCR. FISH indicated the localization of the clock-related transcripts clock, period, and photoreceptive and non-photoreceptive cryptochrome (p- and np-cry) in two bilateral neurons in each cerebropleural ganglion and a group of >6 neurons in the anterolateral region of each pedal ganglion. Double-label experiments confirmed colocalization of all four clock transcripts with each other. Quantitative PCR demonstrated that period, p-cry and np-cry exhibited a significant difference in expression levels over 24 hours, while differential expression of clock transcripts was just under the significance threshold. These data suggest that the putative circadian clock in *Melibe* consists of a small number of identifiable neurons that express circadian genes with a daily rhythm.

P1-232 DUDDLESTON, KD*; CARLSON, KM; GERING, SM; BUCK, CL; Univ. Alaska Anchorage, Northern Arizona Univ.; *knduddleston@alaska.edu*

Reusing is Recycling: Ureolytic Microbes and Urea Nitrogen Salvage in Mammalian Hibernation

Arctic ground squirrels (AGS) are hibernation extremophiles, spending up to 9 months annually in torpor, subsisting on endogenous body reserves of lipid and protein. Urea-nitrogen salvage (UNS)---the diffusion of urea into the gut, its degradation by ureolytic gut microbes, and the subsequent incorporation of microbially-liberated urea-N (MLUN) by the host---is posited as an important N-conservation mechanism of hibernators; however, little is known about the extent to which MLUN contributes to host synthetic processes, the identity, number or activity of ureolytic microbes in the gut, or how these aspects change seasonally. Therefore, we injected squirrels with either unlabeled or $^{15}N/^{13}C$-labeled urea periodically across their annual cycle. The magnitude of gut ureolysis was assessed via quantification of $^{13}CO_2$ in breath. To determine host use of MLUN, tissues were collected for analysis of $\delta^{15}N$. Cecal samples were collected to enumerate ureolytic microbes and determine expression of urease genes, and fecal and cecal samples were collected to isolate and characterize ureolytic bacteria. Enrichment of $^{13}CO_2$ in breath indicates active ureolytic bacteria in the gut in both hibernation and summer euthermia, and several taxonomically diverse ureolytic bacteria were isolated and identified. We further analyzed tissues for $\delta^{15}N$, and enumerated ureolytic bacteria and expression of urease genes in the gut. Our results indicate that AGS contain a diversity of ureolytic gut bacteria that are active across the annual cycle. Differences in $\delta^{15}N$ of control vs experimental AGS will show the degree to which AGS incorporate MLUN, results that hold the potential to show the importance of UNS in lean mass restructuring during hibernation.

P2-264 DUELL, ME; Arizona State University; *meduell@asu.edu*

Size or skill? Learning abilities conserved in miniaturized stingless bees

Body size miniaturization, occurring when species evolve small size compared to ancestors, may cause unique constraints on body form and function. This evolutionary trajectory means that some tissues, and possibly functions, must be economized or eliminated. Despite this, small body size and miniaturization are common. Small animals across taxa have large brains proportional to their body size (Haller's rule). The reasons behind this trend and its effects on behavior are not known, but it is possible that Haller's rule allows for small animals to maintain behavioral function in the face of greater competition and predation risks. In this study, I tested the visual learning abilities of 10 species of stingless bees ranging in body size from 1.5-115mg in order to determine whether small and miniaturized species are behaviorally limited due to their size and whether having proportionally larger brains allows compensation for any limitations. I used a y-maze test with black and white visual patterns that varied by spatial frequency. A sucrose reward was paired with a specific pattern. After introduction to the maze and task, pattern locations were switched. Bees were scored on the ability to choose the correct pattern in 10 bouts. Next they were tested on how many trials were needed to choose the correct pattern 10 consecutive times. Small stingless bee species performed similarly to larger species in both tests, sometimes with greater speed. In order to control for differences in the visual system, I measured eye size, ommatidial size and number, and interommatidial angles. Smaller bee species had slightly larger eyes in proportion to their body size, but they had smaller and fewer ommatidia (worse vision). Together, these data suggest that smaller stingless bee species are not behaviorally limited due to size. The maintenance of behavior in small animals may explain the common occurrence of miniaturization across taxa.

P3-205 DUFFY, JL*; WATSON, CM; Midwestern State University; *jessica.lynnifer@yahoo.com*

Does differences in toepad and claw morphology among Mediterranean House Gecko (Hemidactylus turcicus) populations correspond to properties of their substrate?

Morphological changes can occur rapidly in populations when exposed to new or more intense selective pressures. One instance of acute exposure is the introduction of non-native species into new habitats. While the addition of a non-native species can have profound effects on natives, there can also be large impacts on the invader itself. The Mediterranean House Gecko, *Hemidactylus turcicus*, is native to Southern Europe and Northern Africa and has spread throughout the world as resilient invader. Throughout its evolutionary history, it naturally inhabited rock faces and cracks but now also thrives on human-made walls and other structures. Since these structures are often made of different materials and the gecko relies on lamellar toepads and claws to adhere to vertical structures, we compared toepad area and claw length among four isolated populations with different substrate properties. In the coming year, we hope to expand the dataset and include population-level analyses to better understand this phenomenon in a broader context.

P1-241 DULAL, D*; O'BRIEN, S; Radford University; *ddulal@radford.edu*

Effects of Nonylphenol on Behavior, Development, and Morphology of Gambusia holbrooki.

Endocrine disrupting chemicals (EDCs) are synthetically produced chemicals that interfere with naturally produced hormones by inhibiting or exciting the normal functions of the endocrine system. Nonylphenol (NP) has been associated with high mortality and lifelong abnormalities, but is currently under-studied (Tanaka & Grizzle, 2002). NP is an estrogen mimic and has been used for the production of plastics, pesticides, and cleaning products (detergents). As a result of Increase in production of NP, the safety limit of NP, 7.0 µg/l, in the aquatic system is often breached (EPA, 2010, p.4). Previous studied on Virginian rivers have demonstrated that more than 10% of rivers across Virginia has exceeded 10 µg/l of NP (Ackermann et. al., 2002, p.204). Reduced hatching rates, inhibition of oogenesis in females and testicular tissues in males, hormonal imbalance, and behavioral abnormalities have been documented (Schwaiger et. al., 2002, p.182). Our project, using the *Gambusia holbrooki* (mosquitofish) model, explored sub-lethal effects of high (500 ppb), medium (100 ppb) and low (10 ppb) ecologically relevant doses of NP. Here we elucidate the impact of NP exposure on fish morphology, development, and behavior.

P1-93 DUMAR, ZD*; LEYS, SP; University of Alberta; *dumar@ualberta.ca*

D-aspartate proposed to modulate the inflation-contraction response in the sponge Ephydatia muelleri

All animals must coordinate multiple different cell types in response to environmental stimuli. Rapid responses to environmental stimuli in eumetazoans are performed by the nervous and neuroendocrine systems. However, poriferans lack nerves and so must use other coordination mechanisms. The demosponge *Ephydatia muelleri* uses the local secretion of a variety of small molecules to coordinate responses of tissues. One major response coordinated by small molecules is the inflation-contraction response to rid the sponge of irritants that may interfere with water filtration. A previous study found that glutamate triggers contractions that propagate throughout the body of *E. muelleri*. The same study detected D-aspartate within *E. muelleri*. In eumetazoans D-aspartate is known as a neurotransmitter and modulator of reproductive functions, but its signaling role within *E. muelleri* is currently unknown. We hypothesize that D-aspartate is used, like glutamate, to propagate the inflation-contraction response along tissues in E. *muelleri*. We will first examine *E. muelleri* transcriptome data to verify if the sponge produces transcripts for enzymes necessary in the biosynthesis of D-aspartate. Then we will determine the effect of the application of exogenous D-aspartate on *E. muelleri* individuals in which inflation-contraction is induced. Finally, in-silico analyses on *E. muelleri* enzymes involved in the synthesis or degradation of D-aspartate will be used to select compounds that are most likely to inhibit these enzymes. The effect of these compounds on *E. muelleri* inflation-contraction will then be evaluated. This study will provide insights into the signaling toolkits used by sponges to respond to the selective pressure of avoiding clogging the filter.

P3-27 DUNCAN, AB*; BRANDLEY, NC; SALAZAR, BA; Colorado College; *alex.duncan@coloradocollege.edu*

Visual Acuity Across Grasshoppers: Do Body Size and Behavior Matter?

Visual acuity, the ability to resolve fine spatial details, can vary dramatically between closely related species. Body-size, behavior, ecology, and sex are all factors that may influence an animal's visual acuity. Although many studies have examined visual acuity in insects, knowledge of grasshopper visual acuity is mostly limited to one species. Here, we examine the visual acuity of nine grasshopper species using a radius of curvature estimation (RCE) technique. With this data, we explore two common drivers of acuity: size and behavior. Although length in these species ranges from 25-73mm, no interspecific relationship between size and acuity is found (R^2=.23; p=0.18). To explore if behavior may influence acuity in grasshoppers, we compare band-winged grasshoppers (subfamily Oedipodinae) to non-band-winged grasshoppers. Band-winged grasshoppers are characterized by their colorfully patterned hindwings, which may function as a visual signal for mating, making them likely to have finer visual acuity than grasshoppers without visual signals. Despite their colorful appearance, band-winged grasshoppers typically had coarser spatial vision than expected. This study furthers the exploration of relationships between visual systems, behavior, and morphology.

P3-60 DUNCHEON, EJ*; HOPPER, LM; ALLEN, HC; CHAMPAGNE, AM; University of Southern Indiana, The Ohio State University ; *ejduncheon@eagles.usi.edu*

Disordered Skin Lipids Increase Cutaneous Water Loss in Pigeons at High Temperatures

As ambient temperature (T_A) increases, many animals increase total evaporative water loss (TEWL) to maintain a constant body temperature. In Passerine birds, the increase in TEWL is mainly attributed to an increase in respiratory water loss, whereas water lost through the skin as cutaneous water loss (CWL) increases only modestly. However, pigeons and doves (Columbidae) exhibit an opposite trend, greatly increasing CWL with only a small increase in respiratory water loss. The unique ability of pigeons and doves to greatly increase CWL at high T_A may be attributed to the inherent thermal properties of the skin barrier. In birds, the barrier to CWL is the stratum corneum (SC), the outermost layer of skin comprised of dead cells called corneocytes embedded in a matrix of lipids packed together in layers called lamellae. The ability of lipid molecules to pack tightly together in an ordered arrangement determines the permeability of the SC to water and thus CWL. We measured the CWL of pigeons (*Columba livia*) at 25, 30, 35, 40, and 45° C. We then isolated the SC and used Fourier transform infrared spectroscopy to assess lipid ordering and phase state at the same temperatures. Our results indicate that CWL in pigeons increases as T_A increases, and this increase is associated with a concurrent increase in lipid disorder. Furthermore, lipids in pigeon SC undergo a greater increase in disorder than Passerine birds, further supporting the hypothesis that thermal properties of skin lipids determine an organism's physiological response to increased T_A.

P2-155 DUNCKEL, K*; JUGAN, J; CHAMBERS, DL; Saint Mary's College of California; *kdd3@stmarys-ca.edu*

Impact of Community Dynamics on Osmobiosis in Tardigrades (Phylum Tardigrada)

The call for research primed at disentangling the complexities between an organism's ecology and physiology in relation to community dynamics have largely centered on vertebrate stress. While such investigations are invaluable for conservation efforts, invertebrates also experience physiological stress and are keystone taxa of any system they inhabit. Yet, there is a surprising investigatory void in the physiological stress literature in invertebrates compared to vertebrates. Tardigrades (water bears) are fascinating models for investigating invertebrate stress physiology. They are renowned for their ability to survive extreme stressful events by entering into cryptobiosis, or a prolonged ametabolic response to sub-optimal environmental conditions. Cryptobiosis can take on many forms, with osmobiosis (ametabolic response due to change in ion content) being one of the least understood. We investigated osmobiosis in wild-caught heterotardigrades (*Echiniscidae*) from Contra Costa County, California. More specifically, we sought to determine 1) the impact of increasing water ion content on cryptobiosis and reanimation, and 2) the role of community composition (presence of moss substrate and rotifers, common food sources for most tardigrades) on reanimation from cryptobiotic conditions. Results from our study will add baseline data to tardigrade stress physiology in relation to potential community dynamics as a driving force for reanimation.

P2-141 DUNN, PO*; WHITTINGHAM, LA; Univ. of Wisconsin - Milwaukee; *pdunn@uwm.edu*

Effects of Changing Wind Speed on the Breeding Success of an Aerial Insectivore

Climate change is often thought of in terms of increasing temperatures, however, wind speed is also changing. Surface wind speeds have decreased in the Northern Hemisphere over the past 30 years, but little is known about how this impacts wildlife. In this study we examined the effect of changing wind speed on the abundance of flying insects and the subsequent effects on the breeding success of tree swallows, which are aerial insectivores. We analyzed data collected on wind speed, flying insect abundance and swallow reproductive success over 21 years (1997-2017) at the University of Wisconsin-Milwaukee Field Station in southeast Wisconsin. We found that cumulative wind speed during the breeding season has decreased over the past 21 years. Lower wind speed was associated with greater insect biomass, earlier egg laying and heavier nestlings. Thus, wind speed is decreasing at this location and it is affecting the timing of breeding and potentially the reproductive success of tree swallows.

P2-258 DUNNING, JL; MAZE, SE; ATWOOD, EJ; MURPHY, KK; PRATHER, JF*; Univ. Wyoming; *jprathe2@uwyo.edu*

Neural Pathways Linking Sensory and Motor Brain Regions in Female Songbirds

Females of many species use male courtship displays as a proxy of male fitness to inform decisions of mate choice. Studies of female responses to song have implicated specific auditory cortical regions, such as the caudal mesopallium (CM), in female mate preferences. Here we used an anterograde neural tracer to examine the projections from CM in female Bengalese finches (Lonchura striata). Our results reveal a novel projection from CM to the robust nucleus of the arcopallium (RA) as well as a region we suspect to be the ventral intermediate arcopallium (AIV). These projections may enable CM to influence brain regions implicated in female courtship behaviors. In zebra finches, AIV projects to the ascending auditory stream, which in turn projects to the mediobasal hypothalamus (MBH), a region associated with female copulatory displays. In female Bengalese finches, RA projects to the dorsomedial nucleus of the intercollicular complex (DM), a site necessary for female call production. In addition, DM has recently been shown to project to the cloaca via the respiratory premotor nucleus retroambigualis (RAm). Together, these data reveal pathways through which CM may influence displays and calls in response to preferred song(s). To address the functionality of projections emanating from CM in driving female courtship behaviors, we have begun using an adeno-associated virus encoding the channelrhodopsin protein (ChR2) to selectively and reversibly manipulate CM neurons as female songbirds are engaged in evaluation of song quality. In ongoing experiments, we are testing the prediction that optically induced changes in CM activity while females are listening to song will induce changes in female courtship behaviors.

P1-66 DUQUE, FG*; RODRIGUEZ-SALTOS, CA; CARRUTH, L; WILCZYNSKI, W; Georgia State Univ., Emory Univ.; *fduque1@student.gsu.edu*

High-frequency vocalizations and habitat acoustics in Andean hummingbirds

Species' vocalizations are often tuned to the acoustic features of their habitats to facilitate effective communication. We investigated the relationship between spectral characteristics of calls and habitat noise in some species of Andean hummingbirds which produce high-frequency vocalizations and live in cloud forest and high-altitude grasslands. We tested the hypothesis that high-frequency vocalizations represent adaptations to avoid signal masking generated by ambient noise. The Buff-tailed coronet (*Boissonneaua flavescens*), Speckled hummingbird (*Adelomyia melanogenys*), and Violet-tailed sylph (*Aglaiocercus coelestis*) live in the cloud forest and produce vocalizations with high frequencies (FF=9.046 kHz, FF=10.716 kHz, and FF=11.935 kHz, respectively), compared to other hummingbirds. Environmental noise there occurs in a frequency range between 3-9 kHz in which most other birds sing, and another range from 12.5-15 kHz generated mostly by insects. This suggests that these cloud-forest hummingbirds vocalize at high frequencies to benefit from a 'noise-free' window in their environmental acoustics. Meanwhile, the Ecuadorian Hillstar (*Oreotrochilus chimborazo*) lives in high-altitude grasslands and produces a song with even higher frequencies (FF=14.189 kHz); in this habitat, however, the ambient noise, typically generated by wind, occurs largely below 5 kHz. Our findings suggest that avoidance of signal masking may contribute to the presence of high-frequency vocalizations in the cloud-forest hummingbird species, while other factors may account for the occurrence of the very high-frequency song in the Hillstar.

117-1 DUTEL, H.*; SHARP, A.C.; GRÖNING, F.; SELLES DE LUCAS, V.; WATSON, P.J.; EVANS, S.E.; FAGAN, M.J.; University of Hull, Hull, University College London, London, University of Aberdeen, Aberdeen; *h.dutel@hull.ac.uk*

The role of soft tissues in the skull biomechanics of two lizards

The skulls of many lizards form an open framework of bars and openings, which differ radically from the shell-like, bony skull of mammals. These morphological differences have biomechanical implications. In lizards, strains are generally significantly higher than those of mammals, with less variation between anterior and posterior skull regions. The lightly-built, more flexible skulls of lizards are also supported by more extensive soft tissues than the mammalian skull, such as sheets of fascia over temporal openings, and thick palatal fascia in the oral cavity. Yet, the role of these tissues has been little studied in lizards, despite their likely impact on the strain regime of the skull. For instance, the palatal fascia might allow for the strains to be dissipated from the snout through the palate to the postorbital skull, hence reducing peak strains over the thin bones of the palate. Using the lizard species *Salvator merianae* and *Varanus ornatus* as model organisms, we explore the biomechanical significance of these structures by employing 3D computer-based mechanical simulations based on detailed muscle dissections, and *in vivo data*. First, we simulated muscle activity and joint-reaction forces during biting using Multibody Dynamics Analysis. Next, the forces calculated from these models were used as an input for Finite Element Analysis, to investigate and compare the strains of the skull in these two species. The role of structures, such as the palatal fascia, quadratojugal ligament and post-orbital ligament/bar is investigated and compared between *Salvator* and *Varanus*. In a broader context, these results will serve to determine the relative significance of different soft tissues in reptiles versus mammals.

65-7 DUTTA, B*; MONAENKOVA, D; GOODISMAN, M D; GOLDMAN, D I; Georgia Institute of Technology;
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Prey and mound disassembly, manipulation and transport by fire ant collectives

Social insects work collectively to complete tasks; in many situations individuals can approach a task using different behaviors. For example, fire ants (*S. invicta*) which inhabit subterranean nests covered by a hemispherical mound of soil permeated by narrow (~*1 body length wide tunnels*) can engulf soft-bodied prey via manipulation of the prey, the mound, or both. Given that each ant can perform such manipulations and transport, how does the collective decide which approach to take? Laboratory housed fire ant colonies were offered diverse prey embedded with lead markers, including mealworms, crickets and shrimp. Ant-prey-soil interactions on the nest surface were recorded using overhead video and subsurface using x-ray imaging. Mealworms were collectively carried intact into the mound through a tunnel, and then disassembled within the mound; shrimp was dismantled into small pieces above the surface and carried to mound tunnels; crickets were buried after limb removal and then disassembled and moved into tunnels. Soil reconfiguration occurred in all cases. To systematically understand the hypothesized emergent behaviors, we devised a controllable food item from Semolina flour (*a "suji"*). The shape, size and brittleness of the suji was controlled via the cooking process. These experiments revealed that a brittle suji was more likely to be deconstructed into small pieces before transport into tunnels; less breakable suji was typically buried or transported intact to a tunnel(if the item was small enough). Individual ants involved in feeding exhibited heterogeneity in tasks which included food maneuvering, dissection and mound reconfiguration. We hypothesize that food characteristics (like hardness and size) select for appropriate individual behavior which gives rise to the different engulfment scenarios.

P2-118 DWIVEDI, V*; TRIPATHI, C; MISHRA, H; KHURANA, H; LAL, R; DYAL SINGH COLLEGE, UNIVERSITY OF DELHI, INDIA, UNIVERSITY OF DELHI, INDIA;
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Comparative Genomics of Thermus spp. and Enzymatic Potential of Thermus parvatiensis , Isolated from a Hot Water Spring Located Atop the Himalayan Ranges, India

Thermus parvatiensis strain RL was isolated from a hot water spring (90ºC to 98ºC) located in the Himalayan ranges at Manikaran, India. Its genome was sequenced by using Roche 454 GS (FLX Titanium) system and PacBio RSII SMRT sequencing. The draft sequence of *Thermus parvatiensis* RL represents a genome size of ~2 Mb. Annotation revealed a high number of repair genes, a squeezed genome but containing highly plastic plasmid with transposases, integrases and mobile elements which have proved their role in horizontal gene transfer. In order to highlight the genome structure complexity of members of the genus *Thermus*, we undertook a comparative genomic study with *Thermus parvatiensis* as reference with other published *Thermus* genomes to assess phylogenetic relationships based on 16S rRNA gene sequences, average nucleotide identity, conserved marker genes , pan genome and tetranucleotide frequency. The core genome of the analysed genomes contained 1177 core genes and many singleton genes were detected in individual genomes, reflecting a conserved core but adaptive pan repertoire. The adaptability of species of the genus *Thermus* in general, has highlighted by extreme genome plasticity. Analysis of CRISPRs among *Thermus* spp. reveals presence of abundant defense mechanism in this genus and frequent viral encounters.Additionally, a comparative analysis of competence loci across *Thermus* genomes revealed evidence for recent horizontal acquisition of the locus and continued dispersal among members reflecting that natural competence is a beneficial survival trait. Efforts are also being made to characterize, clone and express the thermostable DNA polymerase I of *Thermus parvatiensis* RL.

140-6 DYMOWSKA, AK*; SEIBEL, BA; University of South Florida; *dymowska@mail.usf.edu*

Ammonium excretion in the pelagic red crab, Pleuroncodes planipes

Pelagic red crab, *Pleuroncodes planipes*, is an important and very abundant component of zooplankton in the Eastern Tropical Pacific Ocean. They inhabit pelagic and benthopelagic zones, with temperatures varying from 10˚C to 28˚C. Similar to other zooplankton species, pelagic red crab make daily migrations to the surface waters to feed. They have also been observed to occasionally aggregate into large swarms on the water surface. Recently, it has been proposed that ammonium supplied by diel vertical migrators plays an important role in ocean nitrogen cycle, since it not only provides nitrogen required for phytoplankton growth, but also fuels bacterial anaerobic ammonium oxidation. In our study, we investigated ammonium excretion rates by *P. planipes* at 10˚C, 15˚C, 20˚C, and 25˚C to encompass temperature range they experience in their natural habitat. We observed that excretion of ammonium increased with increasing temperature. We also investigated whether this increase was reflected in upregulation of the machinery that enables ammonia transport in this animal. In aquatic crabs, the main site of nitrogenous waste excretion is the gill epithelium, and is mediated by specialised cells that host a suite of ion transporting proteins. Using analytical methods we measured abundance and expression of the key proteins that have been proposed to be involved in ammonium excretion, such as Rhesus protein, Na^+/K^+-ATPase, Na^+/H^+-exchanger, and H^+-ATPase.

87-2 EARLY, CM*; JAMES, HF; WITMER, LM; Ohio Univ., Athens, Smithsonian NMNH, Washington, D.C.;
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The bill-tip organ: probing at tactile sensitivity in birds

Some birds have a bill-tip organ, a sensory structure that comprises multiple touch papillae, or groups of mechanoreceptors organized in layers around trigeminal afferent fibers. The bill-tip organ mediates specialized feeding behaviors such as probing for food by providing the high tactile sensitivity needed to, for example, locate prey items by remote touch. Thus, its presence may indicate specialized feeding capabilities in birds, but it is not known whether tactile feeding behaviors and morphological evidence of bill-tip organs are correlated in their distribution among birds. Another potential correlation is between the touch papillae of the bill-tip organ and the foramina that house them in the rostral end of the bill. If the bony foramina in the bill are consistently associated with the soft-tissue touch papillae, then the foramina can serve as proxies for the papillae in skeletal specimens or fossils. Foramina are present on the bills of all birds to some extent, and neurovascular structures other than touch papillae may also be housed in them, so the reliability of this potential osteological correlate is unknown. To explore the validity of these potential anatomical correlates of behavior, the patterns of distribution of foramina on bones of the bill were studied in 60+ species of birds spanning 24 orders. Behavioral data and data on the bill-tip organ were compiled from the literature for qualitative comparison to the studied specimens. Our results indicate that using foramina to predict bill-tip organs or using bill-tip organs to predict specialized feeding behaviors in birds should be done with caution. However, preliminary results from other studies indicate that the size of other components of the trigeminal system may serve as correlates for tactile sensitivity in the bill tip.

S8-9 EATOCK, Ruth Anne; University of Chicago; *eatock@uchicago.edu*
Ion channels in vestibular hair cells and afferents shape the receptor potential, synaptic transmission and spike patterning
The vestibular sensory epithelia of amniotes offer unique opportunities to explore, in a relatively simple circuit, questions of sensory transduction and encoding, synaptic transmission and spike patterning. The vestibular afferent neurons form bouton synaptic contacts on type II hair cells and unique calyceal terminals on type I hair cells, in diverse combinations and morphologies. Synaptic transmission from the type I hair cells onto the calyceal terminals relies on both quantal transmission (release of glutamate from synaptic vesicles) and an unusual nonquantal transmission. Recent work (especially Contini et al., J Physiol 595:777, 2017) shows that the nonquantal response depends on potassium ion (K+) efflux from the hair cell through numerous low-voltage-activated K+-selective ion channels into the extensive synaptic cleft formed by the calyx. Nonquantal and quantal responses can be recorded together or separately in single calyceal terminals; how they are coordinated in daily living is not known. By comparing quantal and nonquantal postsynaptic currents and potentials evoked by deflecting the type I hair cell's hair bundle, we see that nonquantal transmission works in both directions between hair cell and calyx, unlike quantal transmission, and can carry faster signals and drive precise spike timing. The calyx terminal also expresses many ion channels, which have been implicated in synaptic transmission and/or the initiation and patterning of action potentials (spikes). Systematic differences in the ion channels and morphologies of the afferent arbors play complementary roles in setting up the diversity of sensitivity and spike patterning in the vestibular afferent nerve.

41-1 EBERTS, E*; SHANKAR, A; MORADO, M; TATTERSALL, G; WELCH, K; CURLEY, M; AUGER, P; University of Toronto Scarborough, Stony Brook University, Loyola Marymount University, Brock University, Loyola Marymount University; *erich.eberts@mail.utoronto.ca*
Using Thermal Imaging to Detect Torpor in Nesting Hummingbirds
Hummingbirds use energy at extremely high rates due to their high metabolism. Their small size forces them to conserve energy robustly, often going into torpor at night during times of high energetic stress (i.e. when food is scarce, or when they are injured), dramatically reducing their metabolic rate and body temperature. It is unclear what strategies incubating females use to conserve energy while still maintaining sufficient temperatures for healthy development of offspring. We aim to quantify the energetics associated with nesting female hummingbirds using thermal imaging. We predict that in order to incubate their eggs effectively, nesting hummingbirds would be unable to enter torpor. Rather than using deep torpor, hummingbirds may use a shallow metabolic reduction, or shallow hypothermia. Additionally, the degree to which metabolism is decreased is predicted to be dependent on ambient conditions (e.g. temperature, wind, precipitation). This project located 26 active Allen's hummingbird (Selasphorus sasin) nests on the Loyola Marymount University campus in Los Angeles, California between January and May, 2017. Nightly time-lapse thermal images were recorded at 12 of these nests using the FLIR Vue Pro R thermal camera. Analysis of these data and validation of this methodology are on-going. Following this initial investigation, we hope to apply a similar methodology to different species in colder environments, such as the ruby-throated hummingbird (Archilochus colubris) in Toronto, Ontario. This project has important implications for understanding the physiology of how animals cope with extreme, and sometimes conflicting, energetic requirements. It also presents broad applications for citizen science and science education.

S11-3 EDIE, SM*; COLLINS, KS; HUANG, S; ROY, K; VALENTINE, JW; JABLONSKI, D; U. of Chicago, Senckenberg Biodiversity and Climate Research Center, U. of California, San Diego, U. of California, Berkeley; *sedie@uchicago.edu*
Extinction, climate, and the dynamics of biodiversity: Analyses of living and fossil marine bivalves
Standing global biodiversity is a product of differential accumulation and loss of lineages through time and across space. Aiming towards a coupled model of factors that promote and suppress the individual components of diversification, origination and extinction, we focus here on the factors underlying lineage loss and its relation to functional diversity in marine bivalves, a model macroevolutionary system. Functional and taxonomic diversity decline in concert along today's latitudinal gradient from equator to poles. In contrast, functional diversity remained nearly constant through the two mass extinctions that define the Mesozoic and Cenozoic Eras despite a loss of nearly two-thirds of the genus diversity through each episode. This differential response in the two currencies across the latitudinal gradient and the mass extinctions highlights a potential asymmetry in the pressure of diversity-dependent and -independent factors on the biota (e.g. the relative operation of resource-limitation vs. physiology). Similar to the mass extinctions, low-richness functional groups also showed a remarkable resilience to extinction through lower-intensity episodes over the past 65 Myr that appear to correlate with a diversity-independent factor, the rate of temperature change. Exploration of this balance in the operation of diversity-dependent and independent factors on taxonomic and functional diversity now has a sense of urgency given the rising intensity of biodiversity loss in today's oceans.

P2-245 EDSINGER, E*; ONO, N; PNINI, R; ILSLEY, G; MILLER, J; Marine Biological Laboratory, Woods Hole, MA, Okinawa Enetech, Okinawa, Japan, Okinawa Institute of Science and Technology, Okinawa, Japan, Okinawa Institute of Science and Technology, Okinawa, Japan; *eedsinger@mbl.edu*
Social tolerance in the Friendly Octopus, Octopus laqueus.
Octopuses are generally known for solitary and even cannibalistic behavior, complicating laboratory culture of large numbers. A small tropical octopus found in Okinawa, Japan and the greater Indo-Pacific, *Octopus laqueus* live in close proximity in the wild where they may one encounter one another on a regular basis, raising the potential for sociality in this species. As a step toward developing a quantitative assessment of octopus sociality, *O. laqueus* were housed in open communal tanks with fixed size distribution but varying in number of animals, dens, and gender composition. For each individual, den occupancy was tracked daily for about a week. We found that while *O. laqueus* often often chose a solitary den when it was available, they also shared tanks and dens without eating each other or trying to escape. Overall, the experiments suggest that unlike all octopus species studied until now, *O.laqueus* tolerate cohabitants within a tank, den, or shelter, even when not mating. The relaxed disposition and social tolerance of *O. laqueus* make it a promising species for lab work and for development into a genetic model of social behavior in octopuses.

P1-150 EDWARDS, KM*; REZNICK, DN; Univ. of California, Riverside; *kedwa007@ucr.edu*

Morphological Adaptation for Two Feeding Modes in Trinidadian Guppies from High and Low Predation Communities

Guppies (*Poecilia reticulata*) from the Northern Range Mountains of Trinidad co-occur with a diversity of predators in the lower portions of all rivers. Waterfalls limit the upstream distribution of predators, so guppies from upstream localities live in communities with a far lower risk of predation. A consequence of facing less pressure from predators is that these fish are able to reach large population sizes with high densities. This high density creates strong competition between individuals for food resources, which forces a diet shift from a preference for invertebrates in high predation communities towards the consumption of more algae and detritus in low predation communities. The guppy is a member of Cyprinodontiformes, the most basal members of which are generalist suction feeders. This clade also contains more recently diverged specialized "pickers," some of which have in turn evolved a scraping feeding mode. I compared the jaw bones and head shape of guppies from high and low predation sites within two paired streams using geometric morphometrics to test if differences in diet are associated with differences in jaw and head shape. I predict that guppies from high predation localities will be better adapted for picking high quality prey from environmental surfaces or the water column while those from low predation localities will instead be adapted for the non-selective scraping of environmental surfaces. These predictions in turn suggest the following expected differences in the structure of the jaw and shape of the head: a. an anterior shift in the position of the intramandibular joint; b. a wider dentary and premaxilla; and c. asymmetry between the size and shape of the dentary and premaxilla. Specimens were cleared and stained, then photographed through a microscope from various angles. Analysis was done using the tps software series.

98-1 EDWARDS, D/D*; MOORE, P/A; Bowling Green State University; *davide@bgsu.edu*

Predicting the big from the small: hydrodynamically influenced changes in stonefly nymph morphology are related to watershed dynamics

Morphological variation of an organism in stream systems can elucidate a connection to the surrounding hydrologic environment. Of interest in recent years is the use of biological traits to detect, predict, and classify watershed perturbations. We have previously identified correlative evidence of *Acroneuria lycorias* (Plecoptera: Perlidae) body shape morphology and flow regime characteristics of a stream. However, we lacked evidence to suggest if the identified variation is driven by local adaptation, phenotypic and / or developmental plasticity. To help address a mechanism, we collected *A. lycorias* and *A. abnormis* from the Peshekee River, in the Upper Peninsula of Michigan, USA. Individuals were housed under contrasting flow conditions in artificial stream channels for ten weeks. Body shape was quantified on day one and day 70 through two - dimensional geometric morphometrics. In addition, we sampled nine lotic systems over a three-year time-period (2015 - 2017) with and without daily discharge data from United States Geological Survey (USGS) stream gauges. We constructed rainfall-runoff models in U.S. Army Corps software (HEC-HMS) for systems without currently active USGS stream gauges and compared the use of *A. lycorias* body shape as a relative hydrologic indicator. Previous work has shown systems with relatively stable flow and high magnitude harbored individuals with a relatively streamlined body shape. Here we show the potential correlation of watershed attributes to the body shape of *A. lycorias*. As human influence on natural systems increases, particularly in the context of global climate change, the use of organism shape information could holistically be used to infer hydrologic conditions of lotic systems.

114-1 EHRLICH, DE*; SCHOPPIK, D; New York University, Langone Medical Center; *ehrlichde@gmail.com*

Independent Control of Volitional and Reflexive Movements in Larval Zebrafish Locomotion

To locomote stably, animals must coordinate volitional actions that change posture with opposing reflexes that hold posture constant. A single, integrated controller is thought to solve this problem, modulating the very reflexes that stabilize posture in order to adjust it. Here we report that larval zebrafish (Danio rerio) utilize a simpler control scheme featuring independent volitional and reflexive movements. We present behavioral evidence that larvae swim in depth by appending destabilizing trunk rotations to steer with independent rotations to balance. When we manipulated buoyancy to deflect fish up or down, they redirected steering without coordinated changes to their balance reflex. As balance developed and increasingly opposed destabilization-based steering, larvae acquired compensatory use of their pectoral fins to steer. Removing the pectoral fins from older larvae impaired steering but preserved the strong balance reflex. Consequentially, older larvae without fins were strikingly less maneuverable — unable to revert to destabilization-based steering — revealing a rigidity inherent within the framework of independent volitional and reflexive control. Larval zebrafish therefore produce effective but inflexible locomotion by sequencing independent volitional and reflexive movements. These results reveal a simple control scheme that solves the general problem of coordinating volitional movements with the vital reflexes that oppose them.

P2-236 ELIAS, ARC*; TOBALSKE, BW; HARLANDER, AM; ELIAS, Audrey; Univ. of Montana, Missoula, Univ. of Guelph; *audrey.elias@umontana.edu*

Effects of steep descending on hindlimb kinematics in a ground-dwelling bird

The mechanics and control of bipedal locomotion is well studied on level ± 10 deg slopes. However, more-extreme slopes are ecologically relevant for many ground-dwelling birds, including chukar partridge (Galliformes). Such birds are understood to routinely use wing-assisted incline running (WAIR) when ascending steep slopes (> 60 deg), but their methods for descending steep slopes are essentially unknown. To improve understanding of mechanisms of hindlimb control while descending steep slopes, we used high-speed video to measure hindlimb kinematics of chukar (n = 4) walking on slopes ± 35 deg. We hypothesized that the hallux would be the first point of first contact only during descent to facilitate passive arrests. However, the hallux was the point of first contact at every slope condition. Significant changes in kinematics occurred at steep angles, revealing a broader repertoire of body posture and hindlimb movement than would otherwise be indicated if our study was limited to shallower slopes. Knee, ankle, and foot excursion changed significantly over the different slopes. Maximal angles of the knee, ankle, and foot changed significantly with slope. Minimum joint angles did not change significantly except for the knee.

116-5 ELIASON, CM*; HACKETT, SJ; Field Museum of Natural History; *celiason@fieldmuseum.org*
Splashing into water: cranial and biomechanical diversity in a cosmopolitan radiation of birds
Understanding why some groups of organisms have more diverse traits than others remains a key challenge in biology. This challenge stems, in part, from the dynamic interplay between species traits and how individuals use these traits in their daily lives. For example, innovations in foraging behavior can drive morphological diversity by opening up new ways of interacting with the environment, or limit diversity through functional constraints associated with different foraging behaviors. Several classic examples of adaptive radiations in birds show increased variation in ecologically relevant traits. However, these cases focus on geographically narrow adaptive radiations; consider only morphological evolution without a biomechanical approach; or do not investigate tradeoffs with other non-focal traits that might be affected by use of different foraging habitats. Here, we use X-ray computed tomography, biomechanical modeling, and multivariate comparative methods to explore the interplay between foraging behavior and cranial morphology across kingfishers, a global radiation of birds with variable beaks and foraging behaviors, including the archetypal plunge-dive into water. Our results reveal several independent gains of plunge-diving behavior in the group, as well as distinct patterns of morphospace occupation for different foraging behaviors and considerable rate variation among skull regions. Our results have implications for biomimetic design of novel drag-reducing structures and shed light on how macroevolutionary trends relate to changes in the adaptive landscape over evolutionary timescales.

P2-239 ELKHOURY, LD*; CASTRO, MA; FOKIDIS, HB; Rollins College, Winter Park; *lelkhoury@rollins.edu*
Fighting for food: Does food insecurity influence agonistic behavior in the brown anole (Anolis sagrei)?
There is constant competition between animals over necessary resources, such as food, water, and reproductive partners, and aggression is a strategy employed to defend resources. Territorial aggression over access to mates is well-studied, however much less is understood regarding aggression aimed at securing food supplies. During a period of food insecurity, the value of food increases which may increase the motivation for defense. We tested the hypothesis that food insecurity increases agonistic behavior, a term encompassing both direct aggression and associated ritualized display behaviors, in male brown anoles (*Anolis sagrei*). We developed three methods for inducing food insecurity and then measured resulting agonistic behaviors. First, to simulate a complete loss of food availability, lizards were fasted for durations of 24, 48, or 72 hours and then tested against fed control lizards in a video-recorded dyadic encounter, where agonistic behaviors were scored. Second, to simulate an unpredictable food source, the amount and timing of food presentation was randomized and those individuals were again tested in a dyadic encounter against control lizards that had daily access to food with both groups equal in the total amount of calories made available to them. Third, to simulate a decrease in food availability, treatment lizards were fed crickets of a smaller size (i.e., fewer calories) and were tested against control lizards fed the normal caloric amount. Results reveal that current energetic state impacts the propensity towards agonistic behavior, with an upper limit imposed in cases of severe energy deprivation. Current research is focused on the potential role of a neural regulator of food intake, neuropeptide Y, in influencing agonistic behaviors.

129-6 ELLERS, O*; JOHNSON, AS; MOTOKAWA, T; Bowdoin College, Tokyo Institute of Technology; *ajohnson@bowdoin.edu*
Do general theories of locomotion apply to underwater walkers?
Theories explaining animal locomotion abound. None of these theories, however, have been applied to underwater legged locomotion. To adjust and adapt those theories to underwater legged locomotion, we consider sea stars, which locomote using numerous podia that are operated hydraulically. In at least four species of sea stars a coordinated action of podia is used to develop a relatively rapid gait, which is characterized by a marked oscillatory raising and lowering of the center of mass. We have extensive video observations of two of those species, *Protoreaster nodosus* and *Asterias forbesi*. Curiously, any one podium is used only once every three steps. In both species, bounce frequencies decrease and maximum velocities increase exponentially with increasing mass; both trends are similar to those seen in terrestrial walkers but sometimes with different coefficients and exponents. In both species this mode of locomotion is similar to terrestrial walking in that the sea star maintains contact with the ground at all times, but is more similar to terrestrial running in that potential and kinetic energy occur in phase with each other. However, for a given mass, *Protoreaster* move at a slower maximum speed and lower frequency of bounce than do *Asterias*. Even the maximum speeds achieved by these sea stars are quite slow, on the order of mm s^{-1}. Applying existing theories of walking to underwater circumstances requires some modifications to account for forces that are important underwater such as drag, acceleration reaction and buoyancy. Even modified, these theories struggle to account for these very slow speeds. Although the speeds are slow, they may be matters of life and death in predator prey races with snails and other sea stars, possibly in cannibalistic interactions.

P1-107 ELLIOTT, KH*; ELLIS, V; SARA, E; GUIGUENO, MF; McGill Univ., Univ. Lund; *kyle.elliott@mcgill.ca*
Oxygen Carrying Capacity Evolves in Tandem with Oxygen Demand: A Review of Hematocrit Values across the Avian Tree of Life
The evolution of major body plans requires remodelling not only of external features, but also of internal physiology. The evolution of body plans in birds has led to a variety of body plans required for optimizing flight costs, and presumably similar changes have occurred at the level of oxygen carrying capacity to achieve the oxygen demands required for various flight styles. To examine the evolution of oxygen capacity among birds, we analyzed hematocrit (packed cell volume) values from 1547 studies including 238 species from all extant avian orders, as hematocrit is widely measured as an index of oxygen carrying capacity. Hematocrit was highest in specialist flyers, followed by divers, non-specialist fliers and runners. Among non-specialist flyers, hematocrit varied with relative flight costs. Furthermore, bird order, representing large variation in body plans, explained more variation than species or genus. Residual inter-specific variation was associated with age, infection status and captivity, not sex or season. We concluded that the evolution of flight styles among avian orders required remodeling of oxygen carrying capacity. Furthermore, use of hematocrit for conservation physiology should rely on data from similar studies (captivity, age, infection status), but data from other species under similar conditions within the same genus are likely comparable.

63-1 ELLIS, EA*; OAKLEY, TH; Univ. of California, Santa Barbara; *emily.ellis@lifesci.ucsb.edu*

Unexpected Opsin Diversity in an Eyeless, Vertically Migrating, Halocyprid Ostracod

Arthropod eye evolution is a dynamic process, with gain and loss prevalent throughout history. The genomics age has shown that opsin, a primary light-sensing protein in eyes, has an even more dynamic evolutionary history. A further layer of complexity is added when we include phylogenetically and ecologically distinct taxa into the study of opsin evolution, even if they lack eyes. We sequenced the transcriptome of a halocyprid ostracod crustacean, a lineage at least 380 MYA diverged from ostracods with characterized opsins. This lineage is ecologically distinct because it is eyeless, pelagic, and performs diel, vertical migrations. We found that this unique halocyprid expresses more diverse r-opsins than any previously characterized ostracod lineage, with or without eyes. We find that the halocyprid expresses the first ever oligostracan MW1-type opsin and the first ostracod SW-type opsin. Next, we find two copies of MW2-type opsins, similar to the median and lateral-eye specific opsins found in other myodocope ostracods, although halocyprids lack these tissues. These findings show that opsins have had even more losses than previously thought, and we hypothesize that further addition of these unique lineages will increase the estimate of losses even more. Lastly, we highlight the importance of including evolutionarily distinct taxa, even those that lack eyes, to teach us about opsin molecular evolution.

P3-26 ELLIS, EA*; PATEL, R; HENSLEY, NM; CRONIN, TW; OAKLEY, TH; Univ. of California, Santa Barbara, Univ. of Maryland, Baltimore County; *emily.ellis@lifesci.ucsb.edu*

Are We On The Same Wavelength? Color and perception do not match in luminous ostracods

Uncovering the role of sexual selection far past speciation events on a macroevolutionary scale has proven difficult, and a major gap exists in the literature because of it. Population-level studies show a clear link between both sexual selection and diversity accumulation, and male sexual traits and associated female preferences. If population-level processes translate to the macroevolutionary level, we expect to find that male trait and female preference co-evolve. Assortative mating strengthens the match between trait and preference after diversification in either, creating reproductively isolated species. Our recent findings provide robust evidence for the end result of increased speciation at macroevolutionary levels, but predictions on male trait and female preference remain untested in this context. Here, we find divergence in male luminescence color in cypridinid ostracods that produce complex courtship signals to attract females. We estimate the absorbance spectra of photoreceptors in the female eye and compare the absorbance peak to the conspecific male emission spectra peak. We find that male color and female perception are not matched. We find a surprising amount of photoreceptor diversity within species of cypridinid ostracod. This comparative project documents signal and sensory ability, which underlies female preference.

P2-76 ELLISON, AD*; PACE, DA; Cal State Univ, Long Beach; *aimee.ellison@gmail.com*

Determining the Relationship of Protein Metabolism and Phenotypic Plasticity in Larvae of the Sand Dollar, Dendraster excentricus

Larvae of the sand dollar, *Dendraster excentricus*, have significant morphological plasticity when reared at different food concentrations. Our lab has recently observed that *D. excentricus* larvae also exhibit physiological plasticity in response to food levels. While high-fed (10 cells ul^{-1}) larvae grew and developed faster than low-fed larvae (1 cell ul^{-1}), they also possessed higher protein growth efficiency (PGE = protein deposited/protein ingested). This study seeks to understand the biochemical attributes of this phenomenon by determining the rates and costs of protein synthesis in low- and high-fed larvae of *D. excentricus*. Rates of synthesis were 1.4 ng protein hr^{-1} $larvae^{-1}$ at 3 days post-fertilization (DPF). At 7 DPF (4 days after initiation of feeding) rates were 0.47 and 1.13 ng protein hr^{-1} $larvae^{-1}$ for low- and high-fed larvae, respectively. By 27 DPF respective rates increased to 1.68 and 11.6 ng protein hr^{-1} $larvae^{-1}$. Fractional rates (% of total protein pool synthesized per hour) were similar between low- and high-fed larvae at ~ 0.5 % hr^{-1}. Preliminary analysis returned an energetic cost of synthesis that was independent of ration level and similar to other larval echinoderms at ~ 10 J/(mg protein synthesized). Results are further discussed in the context of depositional efficiency and its relationship to PGE. The energetic and biochemical analyses conducted in the study are important for determining if and how the cost and regulation of protein metabolism differs between larvae experiencing different food conditions. Such data will allow for a more mechanistic understanding of how environmental conditions determine larval survival and recruitment

S4-2 ELSHAFIE, SJ*; BEAN, JR; WHITE, LD; Univ. of California, Berkeley & UC Museum of Paleontology, UC Museum of Paleontology; *selshafie@berkeley.edu*

Understanding and Communicating Science as a Narrative

Narrative is the oldest framework of human communication. Neurological studies indicate that narrative structure helps an audience process and recall new information. Although many scientists think that narrative can only be used in works of fiction, storytelling is inherent in many scientific disciplines. We aim to help scientists understand the mechanics of narrative, identify the narrative elements present in their own research, and use those elements to develop storylines for broad audiences. To support the development of science narratives, we use a framework for science storytelling developed in collaboration with artists at Pixar Animation Studios, and the *Understanding Science* flowchart developed by the UC Museum of Paleontology (UCMP). We adapt portions of the *Understanding Science* flowchart, a graphic depicting the nature and process of science, into narrative terms to illustrate the parallels between scientific and story development processes. A series of step-by-step worksheets facilitates story development along with the flowcharts, offering a roadmap for using narratives to communicate science. These new tools can generate narratives from any perspective, such as a scientist conducting a study, a character playing a role in a larger system (e.g., foraminifera or a carbon atom), or an entire system interacting with other systems (e.g., the carbon cycle). We offer exemplar stories about climate change from multiple perspectives, using content and conceptual models from the new UCMP website *Understanding Global Change*. We also explore how these tools can facilitate hands-on learning with lecture-based learning in science classrooms.

S4-1 ELSHAFIE, SJ*; SUMIDA, S; Univ. of California, Berkeley and UC Museum of Paleontology, California State Univ., San Bernardino; *selshafie@berkeley.edu*

Introduction to the Symposium, Science Through Narrative: Engaging Broad Audiences

Due to the politicization of science and the proliferation of misinformation about science and its significance, the ability to articulate clearly the importance of science to the public has never been more crucial. The most effective way to engage an audience with new information is to frame the content within a narrative. Many scientists think that narrative applies only to fiction, but a narrative is simply a sequence of causative events that offer meaning. This applies equally to fiction and fact. Narrative is a universal language understandable and relatable to any audience. Narrative training is nevertheless absent from most science degree and professional development programs. We have therefore organized this symposium to synthesize new approaches to science communication by integrating narrative and artistic techniques from a broad range of industries. In addition to gaining the fundamentals of narrative development, learning from practitioners outside of scientific fields helps scientists to understand the inherent intrigue of their work from non-scientific perspectives. Our speaker list brings together a wide spectrum of scientists and artists, all of whom have experience using both science and art to share their work with general audiences. In this introduction, we introduce the narrative of the symposium itself: a journey through scientific narrative development, visual narrative techniques, and models of collaboration between scientists and artists. NOTE: This introductory talk will be 15 minutes in length and start at 7:45 AM.

119-4 EMBERTS, Z*; ST. MARY, CM; HERRINGTON, T; MILLER, CW; University of Florida, Gainesville; *emberts@ufl.edu*

Losing a leg up on the competition: consequences of losing a sexually-selected weapon

Intraspecific competition over access to females has led to a large diversity of animal weapons. Generally, the relative size and presence of these weapons is positively correlated with mating success, as individuals with the largest weapons often obtain most of the mates. Still, despite their benefits, weapons in many individuals do not grow large. Moreover, in some species, weapons can be lost; for example, beetle horns can be broken and crabs can drop their claws. Previous research has shown that individuals missing their weapons are less successful at male-male competition, but few studies have investigated how this loss translates to changes in mating behavior and mating success. Here, we fill this gap in our knowledge to gain a better understanding of the costs associated with weapon loss. To that end, we investigated how weapon loss affected fighting ability and mating success in *Narnia femorata*, with special emphasis on behavior. We found that the loss of weaponry did not affect fighting behavior, but did affect fighting ability. Furthermore, weaponless males, who were more likely to be subordinate, were less likely to initiate a mating. Therefore, loss of weaponry ultimately decreased mating success. These results raise interesting questions about fighting plasticity and self-assessment.

S3-4 EMERLING, CA; CNRS - Université de Montpellier; *drcaemerling@gmail.com*

Regressed but not gone: Patterns of vision gene loss in blind mammals

Regressive evolution involves the degradation of formerly useful traits as organisms invade novel ecological niches. Committing to a strict subterranean habit can lead to regression of the eye, likely, in large part, due to a limited exposure to light. Several lineages of subterranean mammals show evidence of such degeneration, which can include decreased organization of the retina, malformation of the lens and subcutaneous positioning of the eye, corresponding with a degradation of genomic loci encoding visual functions. However, animals with eyes that are not necessarily degenerate also demonstrate evidence of visual gene loss, such as those modified for enhanced dim light photoreception. Therefore, it is unclear whether there is any substantial difference in the protein-coding visual gene repertoire between subterranean mammals and other dim light-adapted vertebrates, or whether such differences are solely attributable to changes in non-coding regions. Also, the regression of eyes in subterranean mammals is incomplete, raising the question of whether they are trending towards total loss or are being retained for non-image-forming photoreceptive functions. Here I test two hypotheses pertaining to these questions: (1) vision gene loss in subterranean mammals differs in quantity and quality (i.e., functional distribution) from other dim light-adapted vertebrates, such as nocturnal and deep sea species; (2) subterranean mammals retain functional orthologs of some non-pleiotropic visual genes that are evolving at rates consistent with purifying selection. I discuss my findings in the context of eye loss in other animals and regressive evolution as a whole.

107-4 EMLET, R*; SHANKS, A; Univ. Oregon; *remlet@uoregon.edu*

Winter spawning by marine invertebrates on the Oregon coast - time series analyses over three consecutive years

To learn which animals were spawning and the physical correlates of embryo release by adults, we sampled coastal plankton in time series of 72+ consecutive days in each of years, 2014 to 2016 (Jan - mid March). Pump samples were sorted live; distinct phenotypes were counted; and vouchers for these were barcoded (COI or 16S) and identified, when possible, by blasting sequences in Genbank and Bold databases. Lecithotrophic embryos of chitons, gastropods, feather duster worms, several other polychaetes, hoplonemerteans, and other invertebrate taxa were found. Many of the identified taxa were from littoral depths including rocky and sedimentary habitats. Ocean conditions varied tremendously between years as did total embryo abundance. 2014 was a ‘normal' year, with several storms that brought downwelling favorable winds, large waves, and drops in salinity. In 2014, spawning tended to occur in association with large waves, higher temperature, and lower salinity. 2015 was strongly affected by the warm water ‘blob', with high water temperatures (11-13C), and few storms with large waves. While some species spawned during large wave events, lecithotrophic embryos were 10 to 100 times less abundant in 2015 and 2016 compared to 2014. 2016 was a strong El Nino year; temperatures were again high (11-13C), but the ocean was consistently rough (only 2 days with waves < 2m). In 2016, 3 of 5 spawning events were associated with large waves, but many days with large waves did not have spawning events. Over the 3 yrs, a number of taxa consistently spawned only during some but not all large wave events. One hypothesis for gamete release during large wave events caused by storms is that it leads to localized retention of short-lived larvae. Our 2014 data set is consistent with this hypothesis, but the great variation among years suggests others factor play roles in eliciting embryo release.

S2-7 ENG, Carolyn M. *; AZIZI, Emanuel; ROBERTS, Thomas J.; Brown University, Univ. of California, Irvine; *carolyn_eng@brown.edu*

The battle of the bulge: structural determinants of muscle gearing during dynamic contractions

There are many phenomena in muscle that occur as a result of interactions between contractile and structural elements at multiple scales. One of these phenomena is architectural gearing, which is quantified as the ratio of muscle velocity to muscle fiber velocity. Many pennate muscles operate with a gear ratio greater than one because muscles shorten through a combination of muscle fiber shortening and fiber rotation. Within a muscle, gearing is variable across contractions. During low force contractions, muscles operate at high gear while muscles operate at low gear during high force contractions. This variable gearing has a significant impact on muscle performance by allowing for faster contractions for high-speed movements and more forceful contractions at low speeds. We hypothesize that gearing in any given contraction is determined by the dynamic interaction of fiber-generated forces, fluid force transmission, and the elastic behavior of intramuscular connective tissues. Because muscle is isovolumetric, muscle fibers must bulge radially when they shorten. This radial bulging exerts forces on the surrounding fluid at angles orthogonal to the fibers, providing a pathway to load connective tissues that ensheath fibers, fascicles and the whole muscle. The nature of how fluid pressures and fiber forces interact to load connective tissues in three-dimensions remains poorly understood. To date, architectural gearing has primarily been explored under controlled conditions with constant muscle force and maximal muscle activation. We combine modeling and experimental approaches to understand the fundamental interactions that determine gearing during more realistic conditions where muscles are submaximally activated and forces vary dynamically.

P3-198 ENGLISH, LT; The University of Texas at Austin; *englishl@utexas.edu*

Crocodile Fight Club: Late Ontogenetic Development of Osteoderms and Their Role in Social Behavior

All extant crocodilians possess articulating dermal ossifications called osteoderms, which are commonly described as defensive structures against predators. However, casual observations in the literature have implied that crocodilian osteoderms do not fully mature until well after the hatchling stage, which is when the risk of predation is greatest. If osteoderms primarily serve a defensive function they may be expected to experience strong selection to appear earlier in ontogeny. Alternatively, many aspects of crocodilian locomotor, social, and feeding behavior are known to change markedly throughout ontogeny and would be expected to exert different kinds of selective pressures on crocodilians as they grow. Alternative hypotheses of osteoderm function can be tested in part by looking to see which selective pressure shift correlates with osteoderm development. I examined CT scans of individuals at varying ontogenetic stages to assess the timing of osteoderm development and compared it with expectations derived from four hypotheses: (1) osteoderms assist in thermoregulation in larger individuals; (2) their development is constrained by diet; (3) hatchlings are protected by adults and predator self-defense is only necessary later in life; (4) they act as armor in intraspecific conflicts over resources. Eight taxa were represented, including two particularly well-sampled ontogenetic series of *Crocodylus niloticus* and *Caiman yacare*. I found that different regions of the body develop osteoderms at different times, and that osteoderm maturation generally corresponded to a stage when individuals begin competing with adults for territories and resources, shortly before sexual maturity. Thus, the observed pattern is more consistent with osteoderms acting as defensive structures against conspecifics than any other proposed hypothesis.

77-2 ENSMINGER, D*; LANGKILDE, T; OWEN, D; MACLEOD, K; SHERIFF, M; Penn State University; *dls_david@yahoo.com*

Effects of Maternal Stress on Maternal and Offspring Behavior

The phenotypic impacts of stress and the adaptive potential of these stress-effects are of growing interest to the fields of ecology and biology, particularly in these times of increased environmental perturbations. In addition to mediating the link between environmental variability and organismal plasticity, such as through changes in behavior, glucocorticoids (GCs) are also a mechanistic translator between mothers and their offspring. We tested the hypothesis that GCs will alter maternal behavior, egg physiology, and hatchling behavior. We treated wild caught gravid female eastern fence lizards (*Sceloporus undulatus*) daily with transdermal applications of GCs at an ecologically relevant dose (approximating a GC response to a fire ant attack) from capture to oviposition. Eggs were collected and incubated until hatching. GC-treated mothers basked less and were more likely to be in the corner of their home bin then control females. Maternal GC-treatment produced eggs that had higher GCs concentrations. Finally, offspring of GC-treated females hid under the basking log more and responded less to tactile stimulation mimicking an ant attack. These findings reveal that elevated GCs while gravid can impact the mothers, eggs, and offspring; changes which may be adaptive to stressors such as visual predators. These data contribute to our knowledge of maternal stress and suggest that maternal GCs can have beneficial impacts on offspring phenotype.

133-5 ENZOR, LA*; MOSO, E; HANKINS, C; BARRON, MG; US Environmental Protection Agency; *enzor.laura@epa.gov*

Short term Exposure to Elevated pCO_2 and Hypoxia Affects the Cellular Homeostasis of Grass Shrimp, Palaemonetes pugio

Estuarine organisms are adapted to frequent changes in temperature, salinity, pH, and dissolved oxygen (DO) levels. The high productivity of an estuary contributes to large changes in environmental conditions, with organismal respiration enhancing hypoxic zones, and elevating pCO_2 levels. The interactive effects of elevated pCO_2 and hypoxia remain largely unexplored in estuarine organisms, therefore, we investigated how short term (5-day) exposure to the combined effects of elevated pCO_2 (~1300 µatm) and low dissolved oxygen (~2mg/L) impacted the cellular homeostasis of two different life stages of grass shrimp, *Palaemonetes pugio*. We explored levels of oxidative stress by measuring protein carbonyl formation, and the subsequent antioxidant response using superoxide dismutase and catalase enzyme activities. We combined these values with measurements of carbonic anhydrase activity to discern how exposure to elevated pCO_2 and hypoxia can alter acid-base equilibrium and enhance reactive oxygen species formation. The results from this study highlight the short-term energy costs associated with exposure to elevated pCO_2 and hypoxia, and provide information on which life stage, embryo or adult, are the most susceptible to the interactive effects of these environmental stressors.

13-2 ERNST, DA*; FITAK, RR; SCHMIDT, M; DERBY, CD; JOHNSEN, S; LOHMANN, KJ; University of North Carolina, Duke University, Georgia State University, Georgia State University; *dernst@live.unc.edu*

A Magnetic Pulse Induces Differential Gene Expression in the Spiny Lobster Central Nervous System

How animals detect Earth's magnetic field remains a long-standing mystery of sensory biology. The ‘magnetite hypothesis' proposes that the geomagnetic field exerts torque on tiny magnetite crystals, which in turn are connected to the nervous system and provide the physical basis for the magnetic sense. In principle, a strong magnetic pulse might remagnetize permanently magnetic minerals within an animal, thus potentially altering magnetoreceptors based on magnetite. The Caribbean spiny lobster, *Panulirus argus*, has an impressive magnetic sense and is the only invertebrate known to derive both directional and positional information from the geomagnetic field. Previous studies revealed that magnetic material is present in this species, and a magnetic pulse alters lobster orientation, suggesting that lobster magnetoreception is at least partly based on magnetite. However, little is known about the effect of a strong magnetic pulse on the central nervous system (CNS) of spiny lobsters or any other animal. To investigate the effect of a magnetic pulse on the CNS and identify genes associated with magnetoreception pathways, we subjected lobsters to either: (1) a magnetic pulse oriented antiparallel to the horizontal component of the geomagnetic field; or (2) a sham pulse, in which lobsters were handled identically but not pulsed. RNA sequencing was then used to examine gene expression in the brain, subesophageal ganglion, and thoracic ganglia. In all three tissues, numerous genes were differentially expressed, providing novel insights into how a magnetic pulse affects nervous tissue and the putative molecular mechanisms that underlie lobster magnetoreception.

27-3 ESCOBAR-CAMACHO, D*; TAYLOR, MA; CARLETON, KL; University of Maryland, College Park; *descoba2@umd.edu*

Color vision in a cichlid: Metriaclima benetos

Animals vary greatly in color pattern and such patterns often play a role in speciation. Evolutionary biology aims to understand the selective mechanisms shaping color patterns and their perception by conspecifics and heterospecifics. Studies of color vision, the capacity to discriminate color regardless of brightness, are relevant for understanding coloration patterns, visual system sensitivities and visual signals. Combining data on photoreceptor spectral sensitivities, behavioral experiments and physiological models provides a unique opportunity to analyze chromatic discrimination in an integrative approach. Cichlids are some of the most colorful freshwater fishes. Their color patterns can be sexually dimorphic and are likely important for species recognition, mate choice, and speciation. Hence, accurate visual communication is essential for cichlid behavior. Here we demonstrate color vision of a rock-dwelling cichlid from Lake Malawi: *Metriaclima benetos*. We combine behavioral experiments through classical conditioning with physiological models in order to estimate the perceptual thresholds of color contrast. In our experiments we compared fish performance with predictions from an established color vision model, the receptor noise-limited model. Our study produced two main outcomes: First, we demonstrate that *M. benetos* possesses color vision. Fish were more likely to choose the trained stimuli over any distracters, irrespective of brightness. Second, we describe the color thresholds of their chromatic discrimination. Fish were able to discriminate more disparate colors but not more similar ones, allowing us to determine how photoreceptor noise affects color discrimination.

138-5 ESPINOSA-GAYOSSO, A; GHISALBERTI, M; SHIMETA, J*; IVEY, GN; Univ. of Western Australia, Perth, Australia, Univ. of Melbourne, Melbourne, Australia, RMIT Univ., Melbourne, Australia; *jeff.shimeta@rmit.edu.au*

Predicting the Variation of Particle Capture Rates in Aquatic Ecosystems

The recent development of predictive tools for particle capture has opened up new possibilities for the determination of rates of suspension feeding, larval settlement, pollination and sediment removal in aquatic ecosystems. Through the use of computational fluid dynamics simulations and existing experimental data, we demonstrate how the rate of contact between suspended particles and biological collectors is affected by system characteristics such as flow velocity, particle size and collector size. Within the broad parameter space of aquatic ecosystems, the dependence of contact rate on each of these characteristics is shown to be highly variable. The understanding of these dependences has served to reformulate some hypotheses of selection pressure on the physiology and ecology of aquatic organisms. Finally, the benefits and limitations of computational fluid dynamics tools in predicting rates of particle capture are discussed, with a focus on the new avenues of research suggested by these results.

112-3 EVANS, SE*; DROSER, MD; GEHLING, JG; University of California, Riverside, South Australia Museum; *sevan004@ucr.edu*

Growth of the Ediacara Macrofossil Dickinsonia costata: Highly Regulated and Complex Development in one of Earth's Earliest Animals

Early animal evolution is recorded in the soft body fossils of the Ediacara Biota but linking many of these taxa to specific clades has proved challenging, leaving large gaps in our understanding of the evolution of complex life. Many attempts to classify Ediacara taxa focused on shoehorning them into modern groupings have proved largely unsuccessful and contentious. *Dickinsonia* is an abundant member of the Ediacara Biota that has uncertain affinities, with interpretations ranging from annelids to lichen. Here we present analysis of over 900 specimens of *Dickinsonia costata* from the Flinders ranges and surrounding areas in South Australia to asses where it fits in the early evolution of complex, macroscopic life. Morphological observations demonstrate that *D. costata* was a bilaterally symmetric, modular organism without evidence for a mouth, anus or gut. Quantitative analysis suggests isometric growth with respect to length and width to maintain a high surface area to volume ratio. Growth was achieved via posterior addition and subsequent expansion of modules in a complex yet surprisingly well-regulated pattern to maintain an ovoid morphology. The suite of morphological characters identified, along with highly regulated, complex growth suggests that *Dickinsonia* contains some of the features common to bilaterians but not the suite of characters necessary for a bilaterian classification. We propose that this overlap in characters reflects the utilization of gene regulatory networks common to most metazoans and that *Dickinsonia* represents an extinct clade located between sponges and the last common ancestor of Protostomes and Deuterostomes, and likely belongs within the Eumetazoa.

P2-175 EVANS, EE*; HWANG, Y; SUEDA, S; UYENO, TA; Valdosta State University, Texas A&M University; *eeevans@valdosta.edu*

Estimating Whole Body Flexibility in Pacific Hagfish

Without a vertebral column, hagfish are flexible enough to tie body knots. They do this to avoid predation, clean off slime, and enhance toothplate forces during feeding. These behaviors rely on a large range of bending and twisting motions. We developed a virtual MATLAB simulation to further understand the flexibility constraints of these motions. This virtual hagfish physics simulation was composed of 50 rigid links connected serially using spherical joints with movement-resistant springs. However, the simulated movements were not realistic because we lacked basic estimates of whole body flexibility. In this study, we provided the model with realistic estimates of range of motion and degrees of freedom by measuring the tightest loop radius that the body was able to hold passively. We formed and photographed loops along the bodies of freshly euthanized Pacific hagfish (*Eptatretus stoutii*) at points corresponding to 20%, 40%, 60%, & 80% body length. We then skinned the hagfish and performed these same experiments to identify the contribution of the loose skin to whole body flexibility. Photographs were then analyzed with NIH ImageJ to measure average loop radii. *E. stoutii* showed a larger range of lateral movements compared to ventral and especially dorsal movements. We were able to longitudinally twist the bodies between 900º and 1440º depending on the specimens' length/diameter ratios. Range of motion generally increased towards the posterior portion of the body, and skin did not greatly affect range of motion. These passive flexibility measurements, when incorporated into our simulation, produced more realistic movement. To further improve these measurements, we are analyzing loop radii in actively knotting hagfish and in hagfish of different species.

142-6 EWERS-SAUCEDO, C*; PAPPALARDO, P; Zoological Museum of the Christian-Albrechts University, Kiel, Germany, Odum School of Ecology, University of Georgia, Athens, USA; *ewers-saucedo@zoolmuseum.uni-kiel.de*

The adaptive potential of phylogenetically conserved larval development in marine invertebrates

Many marine organisms have an biphasic life cycle. The early phase is the predominant dispersal mechanism in otherwise immotile organisms, resembling therein functionally terrestrial plant seeds. The evolution of these larvae and propagules, especially the diverse larval forms of marine invertebrates, has long interested marine biologists, who focused their efforts on taxa with highly labile larval life history. In the present study, we highlight the adaptive potential of larval development of thoracican barnacles, which are presumably phylogenetically conserved in their life history. To infer their extent of phylogenetic conservatism and adaptive potential, we tested for phylogenetic signal, assessed the fit of assumptions and predictions of two adaptive hypotheses, and compared the fit of multiple models of trait evolution. We identified a strong phylogenetic signal for all larval traits, which traces a well-known broad separation between taxa with planktonic-feeding larvae and aplanktonic larvae. This is, however, unlikely to represent evolutionary constraints, as trait shifts are also present in each taxon. It is also unlikely to be a result of neutral evolution, as the traits did not evolve under a model of Brownian Motion, evident by multiple model comparisons. Moreover, larval developmental mode and egg size exhibit adaptive potential: they match the predictions of both adaptive hypotheses if we allow certain modifications that were shaped by mismatches between assumptions and data. We conclude that the larval development of thoracican barnacles is phylogenetically conserved, but was likely also shaped by selective pressures, which leave adaptive signatures in the current distribution of barnacle larvae.

P3-42 FABELA, FF*; CHAPMAN, JT; OWENS, JD; RANDLES, S; VILLATORO, R; MAY, MA; VASQUEZ, MC; TODGHAM, AE; TOMANEK, L; Cal Poly San Luis Obispo, UC Davis; *rfabela@calpoly.edu*

Ciliary Response in Mytilus californianus to Food Availability and Sirtuin Inhibition

The California mussel (*Mytilus californianus*) is an ecologically important intertidal species and studies of its physiological responses to stress can predict how mussels respond to increasing temperatures. Previous studies have shown that sirtuins (NAD-dependent deacylases) may link food availability and heat acclimation to affect the mussels tolerance to acute heat stress. The mussel's gill plays an integral role in feeding, as cilia create a current within the mussel cavity allowing food to move toward the mouth. The ciliary beat frequency can be used as a measure of the gill's metabolic activity, so we evaluated ciliary responses of *M. californianus* during recovery from acute heat shock and sirtuin inhibition. Mussels were acclimated to one of two temperatures (20°C or 30°C) during low tide and two food rations (0.25% or 1.5% mussel dry weight·day^{-1}) for 3 wk before a subset of the mussels were exposed to sirtuin inhibitors. Subsequently, all mussels were exposed to a 33°C heat shock during emersion. Ciliary activity was monitored from an excised gill section during high tide periods of the 48 h before and after inhibition and heat shock. Four gills from each group were dissected and observed under a microscope on a temperature-controlled slide. Ciliary movements were recorded at 60 fps using a high definition camera over 30 s increments to determine average beat frequency. Given the energy dependence of ciliary activity, we predict that mussels from high food acclimation groups will recover more quickly from an acute heat shock than those from the low food group and will have average beat frequencies similar to those we recorded prior to sirtuin inhibition and heat stress (funded by NSF IOS-1557500).

89-6 FALSO, PG*; NOBLE, CA; ADAME, LC; RODRIGUEZ , SA; NGUYEN , MN; WESTHEAD, ML; HAYES, TB; Slippery Rock University, Univ. of California, Berkeley; *paul.falso@sru.edu*

Native and Invasive Amphibians: A Comparison of Stress and Associated Immune Function Following Agrochemical Exposure

Amphibian populations that occur in degraded habitats, such as those in intensively cultivated agricultural regions, are challenged by a complex set of environmental factors. Effective management of land-use to protect sensitive and declining amphibian species requires an understanding of the relative impact of these factors on individual and population success. In the current study, adult American bullfrogs (*Lithobates catesbeianus*) and Northern leopard frogs (*Lithobates pipiens*), were exposed to a mixture of agrochemicals for 12 days. The American bullfrog is an invasive species with relatively stable populations in California, USA, while the Northern leopard frog is native to California but has experienced dramatic population declines at nearly all historic locations within the state. The agrochemical mixture represented commonly applied pesticides and fertilizers in California, to which both native and invasive species inhabiting the agricultural environment are likely exposed. Following exposure, select endocrine and immune responses were examined in both species. Native declining Northern leopard frogs responded similar to invasive stable American bullfrogs to the specific chemical mixture tested here. Plasma corticosterone, blood cell differentials, and blood cell activity were not significantly altered in either species. Given the ubiquitous presence of aquatic contamination and the importance of disease in amphibian declines, the current study may assist in addressing the relevance of interspecific and life stage sensitivity to agrochemical exposure.

P3-64 FALVO, CA*; WEBB, A; FRENCH, SS; AUBRY, LM; Colorado State University, Utah State University; *Caylee.Falvo@colostate.edu*

Immunity and Growth Trade-offs Vary with Elevation in a Hibernating Small Mammal, Urocitellus armatus

Identifying the ecological factors that shape the evolution of life histories has been a topic of great interest and research for several decades. Populations of the same species can express important differences in life history traits, often apparent when comparing populations along an elevation gradient, where differences in phenology, reproduction, survival, and growth exist. Higher elevations are typically characterized by a shorter growing season, lower temperatures, and limited resources. High elevation individuals must allocate resources among growth, immunity, and reproduction, shaping a different life history strategy than lower elevation populations. However, such trade-offs between fitness traits and immunity have rarely been studied in the wild. We live-trapped Uinta ground squirrels (UGS, *Urocitellus armatus*) to examine the relationship between immune function (measured by bacterial killing assay) and body mass dynamics in two populations located 600 m. apart in elevation while accounting for age and sex. Higher elevation yearlings/adults emerged at a lower body mass but gained mass more quickly, entering estivation at the same body mass as lower elevation UGS. This increase in growth came at a cost, as immune response decreased more rapidly in UGS at the higher elevation, indicating a trade-off between growth and immunity. Interestingly, these trade-offs weren't detected in juveniles, which had similar growth rates and immune response across elevations, with immune function actually increasing over the season. We hope to quantify the consequences of such trade-offs on survival and population growth to predict the ability of UGS to adapt to different climatic conditions and resource phenologies, and understand how UGS and other hibernators may respond to an increasingly variable climate in the future.

P1-28 FANT, JA*; OLIVIERI, RA; EKSTROM, LJ; Wheaton College, MA; *fant_john@wheatoncollege.edu*

Does muscle morphology and composition predict function?

Muscles are multifunctional. During concentric contractions, they shorten quickly to produce motion. During eccentric contractions, they slowly lengthen while activated to dissipate energy and absorb forces. These contractions not only differ in function, but also in the impact they have on the muscles themselves. Whereas concentric contractions do not typically induce much damage, eccentric contractions can injure the sarcomere and tear surrounding connective tissue. Eccentric contractions also induce more damage in large, fast-twitch type II muscle fibres than in small, slow-twitch type I muscle fibres due to ultrastructural differences. Because most animals' muscles regularly perform both types of contractions, studies have primarily focused on short-term muscle damage. However, toads differ: hindlimbs almost exclusively perform concentric contractions for hopping and forelimbs perform eccentric contractions to decelerate into a safe landing. This separation of function provides us with a unique opportunity to determine if long term morphological and compositional strategies have evolved to enhance specialized muscle functions. Preliminary histological results demonstrate that anconeus muscle fibres are significantly smaller and more densely arranged ($1815 \pm 495.6\ \mu m^2$, 262 ± 87.9 cells/mm^2) than plantaris muscle fibres ($3959 \pm 792.6\ \mu m^2$, 190 ± 42.8 cells/mm^2; $p<0.01$ and $n=3$ for both). This indicates that muscle fibre type may be a critical adaptation for both performing the sustained eccentric contractions and protecting the muscles from repeated damage. We are also investigating if differences in amount and type of connective tissue exist to further enhance specialized muscle function.

11-2 FARALLO, VR*; MUÑOZ, MM; MILES, DB; Virginia Tech, Ohio University; *vfarallo@gmail.com*

Niche evolution varies depending on geographic scale: Implications for climate change

Climate change is inducing unprecedented effects on species distributions, and even causing extirpation events. One way to assess the impacts of climate change includes understanding the evolutionary history of species climatic niches. Specifically, we would like to know whether species niches are conserved or divergent across evolutionary timescales. In turn, we can leverage this information to predict whether species will be able to track habitats or even expand into new habitats as conditions change. To date the ways in which micro- and macro-geographic patterns of niche evolution relate, if at all, remain largely unknown. Resolving these patterns would greatly enrich our ability to predict species' responses to global climate change. Here we present research comparing micro- and macroclimate niche evolution in 18 species of plethodontid salamanders. We tested for niche lability using phylogenetic signal, which indicates whether variation among species in climatic traits is correlated with relatedness (higher signal) or evolves independently of relatedness (lower signal). The results showed that patterns of niche conservatism are impacted by the geographic scale of the analysis. Microclimatic variables exhibit stronger phylogenetic signal, indicating that relatedness and phylogenetic inertia shape niche evolution at the microgeographic scale. In contrast, patterns of macroclimatic variation exhibited no phylogenetic signal, indicating high niche lability and no impact of relatedness on variation. Importantly, we discovered that patterns of niche evolution are inverted at distinct geographic scales. As such, it is important for microclimatic measurements to be included in studies of niche evolution and the impacts of climate change.

117-4 FARINA, SC*; LONG, NP; Harvard University, Dickinson College; *stacy.farina@gmail.com*

The multifunctional urohyal and sternohyoideus of flatfishes (Pleuronectiformes)

Novel functions typically arise through the co-option of existing anatomy. This creates a close coupling between the new and existing functions of the associated structures, which is thought to constrain morphological evolution. We examine the anatomy and evolution such a musculoskeletal system -- the flatfish urohyal. Flatfishes (Pleuronectiformes) are a diverse group of laterally compressed fishes with extreme cranial asymmetry. They bury within the sediment using body undulations and fin flicking, and preliminary evidence shows that, like many other fishes, they use jets of water from their gill openings to help fluidize sediment. Because flatfishes lay on their side, only one gill opening is in contact with the substrate, which could reduce their potential jetting capacity. However, flatfishes have a highly modified urohyal that may provide a shunt between the left and right gill cavities. The urohyal is a sesamoid bone that develops within the tendon of the sternohyoideus, a major suction feeding muscle. In most acanthomorph fishes, the urohyal is broad and flat, but in flatfishes, it is sickle-shaped. Our dissections revealed that the sternohyoideus attaches dorsally, medially, and posteriorly in three distinct segments. Manipulation showed that the dorsal segment (encased by a large tendon) rotates the urohyal posterodorsally (possibly to pull the urohyal into shunting orientation), and the medial and posterior segments pull the urohyal posteriorly (for hyoid retraction during suction feeding and ventilation). We characterize the considerable variation in urohyal and sternohyoideus shape across 8 species from 3 families, and we discuss the implications of the multifunctionality of this structure for the evolution and ecology of flatfishes.

67-3 FARLEY, GM*; HARRISON, JS; WISE, MJ; SUTTON, GP; PATEK, SN; Duke University, Roanoke College, University of Bristol; *gmf7@duke.edu*

Leaping larvae: hydrostatic jumpers at the mm-scale

The elastic jumps of small insects are typically powered by elongate legs and accessory elastic structures; however, in earlier stages of development, many insect larvae have worm-like bodies without legs, potentially limiting their ability to disperse or escape predation. Here we present a kinematic and energetic analysis of a larval insect that can jump effectively without the use of legs and that instead uses hydrostatic control to launch itself into the air. We studied gall midge larvae (Cecidomyiidae: *Asphondylia* sp.) that form galls within the silverrod, *Solidago bicolor*. The midge larvae express this capability during only the final (third) instar within the gall. When extracted from the gall, they coil their body, brace their mouthparts against the tail, hydrostatically load their small bodies and then jump. During this process, a transient launching "leg" is formed from an otherwise worm-like body form. We analyzed the kinematics of their jumps off of a hard substrate (14 animals, 42 jumps, 1-7 jumps per individual). They accelerated on the order of 104 m/s2, with an average velocity of 1.1 m/s which is equivalent to approximately 350 body lengths/s. They traveled a horizontal distance of an average 27 body lengths and up to 40 body lengths. Our theoretical models suggest that environmental losses, such as drag, reduced jump distance dramatically in addition to energetic losses due to rapid body spinning. Surprisingly, our kinematic results align these small hydrostatic jumpers with the capabilities of the renowned elastic, legged jumps of fleas.

P1-243 FARMER, JL*; GEDULDIG, JG; LITWA, HP; TRICOLA, GM; SISSON, ZR; HAUSSMANN, BD; PAITZ, RT; HAUSSMANN, MF; Bucknell University, Illinois State University; *jlf032@bucknell.edu*

The relationship between glucocorticoid levels at baseline and during an acute stress response

During unpredictable events, vertebrates initiate a physiological stress response, in part mediated by glucocorticoid hormones (GCs) released by the hypothalamic-pituitary-adrenal (HPA) axis. In circulation, GCs generally remain at baseline levels, with mild fluctuations reflecting predictable energetic demands. During stress, however, GC levels become elevated above baseline, which functions to mobilize glucose reserves and inhibit nonessential functions. Once the stressor has passed, homeostasis is restored and GC levels recover to baseline. An acute stress response, then, can generally be simplified to three GC levels: baseline, stress-induced rise, and homeostatic-recovery. Here, we studied Japanese quail (*Coturnix japonica*) using a standard bag-restraint protocol to investigate relationships between baseline GCs and either the stress-induced rise of GCs, or the homeostatic-recovery of GC levels. Specifically, we used dexamethasone, a synthetic GC that causes negative feedback on the HPA axis, to measure homeostatic-recovery. We found that GC levels at baseline correlated negatively with both the GC stress-induced rise and the GC recovery back to baseline. In other words, birds with lower baseline GC levels had a steeper increase in circulating GCs during an acute stress response and also showed a faster decrease in GCs after the stressor was removed. Our results suggest that an individual's baseline GC level relates to their ability both to turn on, and turn off an acute stress response.

P3-192 FARNKOPF, IC*; USIP, SE; MCBURNEY, DL; THEWISSEN, JGM; Kent State University, OH and Northeast Ohio Medical University, Rootstown, OH, Northeast Ohio Medical University, Rootstown, OH; *ifarnkop@kent.edu*

Ontogeny of the respiratory tract in dolphins

With adaptations for an aquatic lifestyle, toothed whales have blowholes and nasal passages that bear little resemblance to those of their land relatives. We used CT scanning and histological sectioning to understand the formation of the respiratory tract during development, using a complete ontogenetic series of dolphins of the genus *Stenella*. We found that the nasal placode develops just superior to the upper lip, similar to land mammals. In the first few weeks of development, the nasal opening shifts caudal onto the forehead. At Carnegie stage 16-17 (around week 5-6 of gestation), dolphin embryos display two external nares. Soon thereafter, these merge to form one blowhole. Around this time (Carnegie 16-19), asymmetry of the nasal opening arises, with the right side elevated above the surface of the forehead. Around Carnegie 20 (roughly 3 months), the single blowhole is oriented obliquely on the forehead, with its right side more dorsal than the left. Even at Carnegie 17, the larynx displays the typical cetacean shape, with spout-shaped epiglottic and corniculate cartilages that project towards but not into the nasopharyngeal duct. Around Carnegie 17, the diverticula of the nasal passages develop, particularly the premaxillary sacs, with few signs of the other air sacs involved in sound production. Understanding the development of the respiratory tract informs the interpretation of nasal passages in Eocene whales and baleen whales. A comparison with Eocene whales indicates that the nasopharyngeal duct anatomy is very different from that of modern dolphins, suggesting differences in the function of the air and food pathways.

P3-77 FARTHING, S.*; MONTALVO, A.; NORMAN, K.; SCOTT, S.; CROZIER, J.; JORGENSEN, D.; Roanoke College; *Sjfarthing@mail.roanoke.edu*

The Role of Tissues and Organs in the Immune Response of the American Lobster to Acute Bacterial Infection

In response to an acute bacterial infection, the American lobster elicits an immune response allowing for rapid clearance of the bacteria from the circulation. Hemocytes (phagocytic immune cells) are mobilized in the circulating hemolymph and their numbers fluctuate in an inverse manner to hemolymph bacterial numbers during the clearance process. It is clear that the circulating hemocytes participate directly in the clearance process. But, are circulating hemocytes responsible for the bulk of the clearance, or are bacteria sequestered in the tissues and organs as well by fixed hemocytes or by some other means? We employed two methods to assess the role of the hemocytes and tissues/organs in the clearance effort. Whole organ culture was employed to quantify the number of culturable bacteria (i.e., those not engulfed by immune cells) in a tissue/organ. We also employed qPCR to determine the total number of bacterial cells (including non-culturable cells - those that had been engulfed) sequestered by a tissue/organ. The gills have previously been suggested to be of primary importance in hemocyte/bacterial cell sequestration, but our results indicate that other tissues/organs (e.g., heart and antennal glands) may play an even greater role in the immune response.

73-6 FARUQUE, IA*; MUIJRES, FT; MACFARLANE, KM; KEHLENBECK, A; HUMBERT, JS; Oklahoma State University, Wageningen University, University of Maryland, College Park, Aurora Flight Sciences, University of Colorado, Boulder; *i.faruque@okstate.edu*

Integrated Sensorimotor Target Extraction Techniques in Untethered Drosophila Flight Control

Insects provide attractive models for micro aerial vehicle development because they achieve robust flight performance in cluttered and unstructured environments despite the relatively limited neural capability of their sensing, actuation, and control structures when compared with vertebrate flight. What feedback strategies do insects incorporate to regulate themselves to desired trajectories? We investigated this question by digitizing the flight of freely-flying fruit flies (*Drosophila hydei*). Three high-speed digital video cameras were used to digitize wing and body kinematics, from which sections approximating stabilized were extracted. Inverse optimal control techniques were applied to examine the composite function of the insect's integrated sensorimotor feedback. This control extraction technique provides progress towards combining the study of individual sensors and tethered laboratory responses by using untethered trajectory information to quantify the structure, performance, and optimal control targets of the integrated sensors and neural feedback.

62-1 FASSBINDER-ORTH, C. A.*; KILLPACK, T. L.; GOTO, D. S.; RAINWATER, E. L.; SHEARN-BOCHSLER, V. ; Creighton University, Salem State University, USGS National Wildlife Health Center; *carolfassbinder-orth@creighton.edu*

High costs of infection: Alphavirus infection reduces digestive function and bone and feather growth in nestling house sparrows (Passer domesticus)

Alphaviruses are arthropod-borne, single-stranded RNA (ssRNA) viruses ("arboviruses") responsible for millions of cases of human illnesses each year. Buggy Creek virus (BCRV) is a unique alphavirus that it is transmitted by a cimicid insect, the swallow bug, and is amplified in two avian species: the house sparrow (*Passer domesticus*) and the cliff swallow (*Petrochelidon pyrrhonota*). BCRV, like many alphaviruses, exhibits age-dependent susceptibility where the young are most susceptible to developing disease and exhibit a high mortality rate. However, alphavirus disease etiology in nestling birds is unknown. In this study, we infected nestling house sparrows with Buggy Creek virus and measured virological, pathological, growth, and digestive parameters following infection. Buggy Creek virus caused severe encephalitis in all infected nestlings, and the viral concentration in brain tissue was over 100 times greater than any other tissue. Growth, tissue development, and digestive function were all significantly impaired during BCRV infection, but based on histopathological analysis performed, this impairment does not appear to be the result of direct tissue damage by the virus, but likely caused by encephalitis and neuronal invasion and impairment of the central nervous system. This is the first study to examine the course of alphavirus diseases in nestling birds and these results will improve our understanding of age-dependent infections of alphaviruses in vertebrate hosts.

70-5 FATH, M*; RIPLEY, D; WINWOOD-SMITH, H; TYTELL, E.D; JOHANSEN, J.L; STEFFENSEN, J.F; DOMENICI, P; Tufts University, University of Manchester, University of Queensland, University of Texas, Marine Science Institute, University of Copenhagen, CNR - IAMC, Istituto per l'Ambiente Marino Costiero; *michael.fath@tufts.edu*

The Effects of Unsteady Flow on the Kinematics of Pectoral Fin Swimming in the Tube-snout (Aulorhynchus flavidus)

Fish regularly experience unsteady flows in nature, but the majority of laboratory studies on fish swimming are conducted under steady flow conditions. Relatively few studies have examined swimming in unsteady flows. Some recent work has investigated how changes in amplitude of wave-like flow affect swimming performance in a pectoral fin swimmer, *Cymatogaster aggregata*. They found that fish with greater variation in fin beat duration were better at holding position in an unsteady flow. Here we explore the effects of different wave frequencies on the kinematics of the tube-snout (*Aulorhynchus flavidus*), a drag-based swimmer. We swam ten tube-snouts in steady flow conditions at four flow speeds and in two unsteady flow conditions. Unsteady flows were composed of a sinusoidal change in velocity with two different periods (0.2 and 0.4 Hz). Changes in velocity were achieved by controlling the voltage input to the motor with a sine wave function. The amplitude of the velocity wave was the same in both unsteady flow conditions, ranging from approximately 0.5 body lengths/s to approximately 2 body lengths/s. Under unsteady flow conditions fish increased fin beat frequency as the water velocity increased and reached a maximum fin beat frequency just before the water flow reached maximum velocity. These results indicate that fish exposed to an unsteady flow change their fin beat kinematics throughout the course of the wave, probably to help them maintain a stable position.

63-2 FAULKES, Z*; SEGURA, S; GARCIA, L; TERRY, J; TERRY, M; The University of Texas Rio Grande Valley; *zen.faulkes@utrgv.edu*

Blind sand crabs have visual opsins

Sand crabs (*Lepidopa benedicti*) have a pelagic larval stage with typical compound eyes, but metamorphose into adults with small vestigial eyespots. These adults dig into sand and live under it for the almost all their lives, apparently only emerging into the waters above rarely and by accident. Light penetrates about 6 mm into sand at most, and adults typically bury themselves about 20 mm under sand. When placed in sand so shallow they are unable to cover their eyes, adults showed no preferences for light or dark areas in a tank. Their eyes do not show the typical facets of arthropod compound eyes. Thus, their habitat, behaviour, and morphology is consistent with these animals being blind as adults. But transcriptomes of entire adult sand crab heads contain multiple opsins, including sequences similar short, medium, and long wavelength opsins of other species. We are now using in situ hybridization techniques to determine whether these opsins are expressed in brain tissue and/or the eyes of adult *L. benedicti*.

73-2 FEASTER, JO*; BATTAGLIA, F; BAYANDOR, J; The State University of New York at Buffalo; *jfeaster@vt.edu*

The Effect of Morphologically Representative Corrugation on Hovering Bee Flight

The present work explores the influence of morphologically representative wing corrugation in three-dimensional symmetric hovering. The kinematics are applied to a processed µCT scan of a *Bombus pensylvanicus* and compared with a wing utilizing the same planform but a flat, rectangular cross-section. The *Bombus pensylvanicus* wing used in the present study was captured in Virginia, killed with Ethyl acetate dying with wings extended with the fore and hind wings connected by the wing humuli. The aerodynamics resulting from geometric di erences between the true wing and flat plate are quantified using C_L and C_D, and qualified using slices of vorticity and pressure. Three-dimensional flow structures are visualized using vorticity magnitude and streamlines. The present analysis is to begin to determine and understand the e ects of insect wing venation on aerodynamic performance and further, to better understand the e ects of assuming a simplified cross-sectional geometry.

P3-154 FEEZELL, MK*; KRETSCHMAR, AC; GONZALEZ, SJ; MAY, MA; VASQUEZ, MC; TODGHAM, AE; TOMANEK, L; Cal Poly San Luis Obispo, UC Davis; *mfeezell@calpoly.edu*

The effect of food availability on siphon opening in the California mussel

Intertidal *Mytilus californianus* are subjected to rapid changes in temperature and food availability. Understanding how mussels deal with these environmental variables can help us predict how future changes in their environment will affect mussel populations. In mussels, the ability to respond to thermal stress may depend on food availability and previous thermal history, which may be linked to the activity of sirtuins (NAD-dependent deacylases). To better understand the role of sirtuins, we evaluated changes in the whole organism physiology for mussels that had been acclimated to one combination of maximum daily temperature (20 or 30°C) and food ration (0.25 or 1.5% mussel dry weight·day^{-1}). Bivalves filter feed via an exhalant siphon, which they open depending on temperature and food availability; this may be used to assess recovery following the application of a stressor. We obtained baseline siphon activity by monitoring siphon movements using high-definition video in the four groups during the last 48 h of a 3 wk acclimation period. We then exposed a subset of these mussels to sirtuin inhibitors and, following inhibition, subjected all treatment groups to an acute heat stress during emersion (33°C). Siphon activity was recorded during the 48 h following sirtuin inhibition and/or acute heat stress to determine how sirtuins and acclimation can affect recovery and the behavior of mussels. We predict that siphon opening will vary among the low and high food regimes during the baseline measurements, and that mussels that received sirtuin inhibition, as well as those acclimated to low food, will recover more slowly from the acute stress than those that were well fed (funded by NSF IOS-1557500).

9-7 FEHRENBACH, LA*; TRACY, CR; RICHMOND, J; California State University, Fullerton, Boyd Deep Canyon Desert Research Center, USGS; *lfehrenbach@fullerton.edu*

The Plestiodon Story: Differences in Physiology between Two Closely Related Skink Species that Differ in Habitat Aridity.

Plestiodon skiltonianus and Plestiodon gilberti are two closely related skink species located in Western North and Central America. P. gilberti is thought to have evolved a larger body size from P. skiltonianus to deal with heat flux across the skin as it moved into warmer and more water restricting habitats. P. skiltonianus is usually found in cooler and higher elevation habitats while P. gilberti can be found in warmer and lower-elevation habitats. Both species can be found in areas of sympatry, however these areas are patchy and intermixed between areas of allopatry. This experiment was done to test inter/intraspecific physiological differences in sympatric and allopatric populations of both species. It was hypothesized that there would be significant physiological differences between all populations tested. To test physiological differences, burst sprint speed, critical maximum and minimum temperatures, and preferred temperature was taken. Respirometry (oxygen consumption rates, carbon dioxide production rates, and evaporative water loss rates) was performed at a range of temperatures both species experience in the field. Preliminary analyses show interspecific differences in optimal temperature, preferred temperature, and critical maximum and minimum temperatures, and evaporative water loss rates. These results suggest that moving into a more-xeric habitat resulted in a physiological shift along in P. gilberti with the increase in body size. Also, each species retains a physiological plasticity when sympatric and allopatric populations of the same species are compared.

P2-202 FEILICH, KL*; DI SANTO, V; LAUDER, GV; University of Michigan, Harvard University; *kfeilich@umich.edu*

How Not to Measure Fish Acceleration Kinematics: An Exploration of Possible Approaches

Fishes use many different combinations of fin and body kinematics to get around in aquatic environments. In order to study this variation in a functional context, we need methods of quantitatively describing and comparing these kinematic strategies. Approaches to quantifying steady swimming gaits have recently been developed. These approaches, while valuable, cannot be applied to the many, biologically important unsteady swimming behaviors that characterize fish movement, e.g. escapes from predators and linear accelerations towards prey. Based on the approaches established for steady swimming, we used several different (admittedly simplified) analytical schemes to try to quantify fish caudal fin acceleration kinematics in bass and trout. We examined three different observer-defined behaviors: steady swimming, linear acceleration, and burst acceleration, over a range of initial speeds, to assess how these approaches capture behavioral variation. The analyses, based on techniques used in digital signal processing, trigonometry, and regression modeling, are limited, but each provides information relating kinematics to acceleration performance. Given their limitations, the approaches presented are intended to invite discussion regarding which quantitative tools we have at our disposal to study unsteady swimming kinematics, and how we might apply them. These preliminary approaches underscore the complexity of fish kinematics, and the need for multi-fin, multi-variate methods.

P1-184 FEIPEL, C. W.*; TATUM PARKER , T; Saint Xavier University; *feipel.c01@mymail.sxu.edu*

Bisphenol A's impact on the germination and growth rate of Brassica rapa.

Bisphenol A (BPA) is an organic synthetic compound that is soluble in organic solvents, commercially used since 1957. It is used to make plastics and epoxy resins and is commonly found in items such as water bottles, canned goods, water pipes, and is even used to line cardboard containers like juice boxes. The presence of BPA in consumer goods and its ability to leach into its surroundings after the plastic item is discarded has an impact on humans and the environment. There is a known link between BPA and increased risk of obesity, genetic modification, and decreased female reproductive fitness in humans. While the medical concerns in humans are the subject of many current studies, the environmental effects of BPA are far less studied. BPA entering bodies of water can cause harm to wildlife, where it can enter the food chain through the water table. We hypothesize that BPA would affect the fitness of *Brassica rapa*, the Wisconsin Fast Plant. We chose this model species because it is considered a common phytoremediator, a plant commonly used to offset pollutants in soils and water sources. We exposed *B. rapa* to BPA in six concentrations between 0.05mg/L and 50mg/L. We collected germination and growth rates, as well as wet/dry weight and root/leaf morphology as a proxy for overall fitness. After this initial study, we hope to continue experimentation with BPA on both native plant species and other model species, to examine larger ecological effects.

P1-62 FEITHEN, W. D.*; KROHMER, R. W.; Saint Xavier University; *feithen.w01@mymail.sxu.edu*

Visualization of C-FOS in the Brain of Timed-Mated Female Red-Sided Garter Snakes

Much of the neural circuitry involved in mediating mating behavior in both male and female vertebrates has been confirmed by tracking the activation of intermediate early genes (IEG). In neurons, these genes are activated early during signal transduction resulting in the expression of specific genes. The presence of specific proteins such as fos, jun and egr-1 families are believed to indicate the initial activation of the genetic machinery of neurons. This study was designed to investigate if mating activates an intermediate early gene in the female red-sided garter snake brain by visualizing the protein c-fos, at specific time intervals following mating. Little is known about c-fos in reptiles. However, it has been reported that in other animals, specific stimuli activate the production of c-fos. It is our hypothesis that following the stimulus of courtship and mating, c-fos will be found within the neural pathways that regulate courtship behavior and mating. C-fos was observed in the brains of time-mated females beginning at time-20 minutes and continuing until time-45 minutes. However, no c-fos was observed in controls, or time-0 or 60 minutes. These initial data have identified a window in which we observed the presence of c-fos production following mating. Further investigation will allow us to refine and define the specific window of c-fos activation by examining post-mated females over a larger number of time intervals.

26-5 FELICE, RN*; GOSWAMI, A; University College London; *ryanfelice@gmail.com*

Development Shapes Mosaic Evolution in Bird Skulls

Mosaic evolution describes the presence of a mixture of derived and pleisomorphic characteristics. This condition can be generated as a result of interrelated clusters of traits, or modules, evolving with different tempo and mode. Mosaicism is a major factor shaping avian evolution: for example, the dissociation of the hind limb and forelimb allowed for the diversification of locomotor behaviours and the radiation of crown birds. We evaluate cranial modularity in birds using high-dimensional geometric morphometrics in a broad taxonomic sample (352 species) and find that the skull, like the post-cranium, is highly modular. We show that evolutionary dynamics are heterogeneous among modules and that evolutionary rate is linked to developmental origin. The face and cranial vault evolve faster than the basicranium and jaw joint. Fast-evolving regions are derived from anterior mandibular-stream cranial neural crest (CNC), or from multiple embryonic cell populations, compared to slow-evolving regions that develop from mesoderm or posterior mandibular CNC only. Evolutionary rates are also variable across the avian phylogeny, with each module showing unique patterns. For example, the rostrum is characterized by punctuated evolution at the origin of major clades, whereas cranial vault shows high rates in lineages with ornamental structures. Taken together, these findings illustrate that the modular organization of the avian cranium allowed for semi-independent tempo and mode across skull regions, facilitating the diversification of birds.

96-4 FELLER, KD*; SUTTON, G; GONZALEZ-BELLIDO, PT; University of Cambridge, University of Bristol; *kate.feller@gmail.com*

Neural control in a striking crustacean, Squilla mantis (Stomatopoda)

One of the most striking features of stomatopod crustaceans, commonly known as mantis shrimp, are the large raptorial appendages that they rapidly and ballistically deploy at targets. These spring-loaded appendages are released during a variety of behaviors, including defense, predation, and habitat manipulation. Though some mantis shrimp can strike at speeds greater than 80 miles per hour, the speed of a strike is highly variable both within an individual as well as among species. In general, species that are specialized to smash hard targets strike much faster than species specialized to spear soft-bodied prey. Using extracellular electrophysiology and high-speed video analysis we investigated how neural activity varies as a function of strike speed in the spot-tail mantis shrimp, *Squilla mantis*, a spear-type stomatopod. These data reveal distinct variations in neural activity between slow extensions of the limb versus fast strikes. Our electrophysiology results also revealed that strike speed can be predicted by the relative timing of high amplitude spikes in the extensor muscle prior to limb deployment. Also presented are the results from our high-speed video analysis of the kinematics of *S. mantis* strikes performed in air vs. water. These results provide the groundwork necessary to inform further research characterizing the neural mechanisms that underlie targeting and deployment of stomatopod strikes.

P1-159 FENNELL, S/A*; MEYER, N/P; MCALISTER, J/S; College of the Holy Cross, Clark University; *safenn18@g.holycross.edu*
Patterns of nervous system growth associated with larval feeding structure plasticity
The expression and evolution of phenotypic plasticity of feeding structures have been examined in sea urchin larvae. Larvae reared in low food conditions grow longer ciliated, skeleton-supported "arms" that are used for feeding, than genetically similar counterparts reared in high food conditions. Sea urchin larvae are also classic model organisms for the examination of developmental processes and mechanisms. Some research has begun to elucidate the molecular mechanisms underlying the plastic expression of larval arms during the initial hours to days of development. However, no research has explicitly examined morphological changes or trade-offs associated with nervous system structure and development between low and high fed larvae reared throughout the entirety of the larval period. These changes are to be expected, as nervous systems are notoriously plastic, forging and breaking connections among neurons and effectors in response to a host of internal and external factors. We are examining morphological differences in the nerves of the feeding arms and food-processing stomachs of larvae of the sea urchin, *Lytechinus variegatus*, using fluorescent staining and confocal microscopy. From these experiments, we anticipate finding differences in nervous system morphology and patterns of expression in these areas. The data we collect will elucidate the effects of plasticity in invertebrate nervous system development in response to external food resources. Further, these data will shed light on the patterns of nervous system development and growth that larvae may experience throughout the duration of the pre-metamorphic larval stage.

46-1 FEO, TJ*; MCCOY, DE; HARVEY, TA; PRUM, RO; Smithsonian Institution, NMNH, Harvard Museum of Comparative Zoology, Yale University, Yale University; *FeoT@si.edu*
Super Black is the New Black: Structural Absorption by Barbule Microstructures of Super Black Bird of Paradise Feathers
Considerable progress has been made in our understanding of how pigments and nanostructures within the feather contribute to plumage coloration. However, external surface structures can also significantly impact visual appearance, such as when surface structures cause multiple scattering of light, leading to nearly complete, incremental absorption of light or "structural absorption". Structural absorption by super black materials is of great interest to materials science due to a wide variety of technological applications. Biological examples of structural absorption have been previously discovered in butterfly and snake scales. Here, we show that feathers from 5 species of birds of paradise (Aves: Paradisaeidae) structurally absorb incident light to produce extremely low-reflectance, super black plumages. Directional reflectance of super black feathers were one or two orders of magnitude less than normal black feathers. SEM and nano-CT revealed highly modified barbules in super black feathers. Ray tracing simulations using 3D tomographic models of feather surfaces confirm that the modified barbule morphology of super black feathers cause more multiple scattering of light, resulting in more structural absorption, than normal black feathers. Furthermore, super black feathers exhibited extreme directional bias in reflectance such that they always appear darkest when viewed from a specific direction. We hypothesize that structurally absorbing super black plumage evolved to enhance the perceived brilliance of adjacent color patches during male courtship display.

P1-87 FERGUSON, SM*; GILSON, LN; BATEMAN, PW; Curtin University; *stephen.ferguson1@curtin.edu.au*
Early birds need the "worm": nectarivore flight initiation distance varies with time of day
Optimal escape theory predicts that animals should flee from predators when the cost of staying outweighs the cost of flight. Potential costs and, consequently, antipredator responses then can be expected to vary under different conditions, such as with the perceived level of the threat or according to individual condition. Nectar-feeding birds typically have a poor capacity for energy storage and thus should exhibit robust diel variation in antipredator behavior that is driven by foraging motivation. Antipredator responses are commonly measured using flight initiation distance (FID), the distance at which an individual flees from an approaching predator. Using the nectarivorous New Holland honeyeater (*Phylidonyris novaehollandiae*) we hypothesized that FID varies throughout the day, predicting shorter FIDs in the morning and evening than at midday, following from and in preparation for the overnight fast, with greater FIDs at midday. In addition, we asked whether escape mode (hop vs. flight) varied throughout the day, according to their presumed nutritional status and the energetic cost of the escape mode. We found evidence of a quadratic relationship between FID and time of day, with relatively shorter FIDs in the morning and evening than at midday ($F_{3,82} = 16.41$, $R^2 = 0.35$, $p < 0.001$). Honeyeaters were increasingly likely to fly to escape as the day progressed (OR = 1.27, CI = 1.11 - 1.49, $p < 0.001$). These results suggest that New Holland honeyeater FID responses support economic models of optimal escape theory, varying with individual energetic needs over the day.

P2-151 FERNANDEZ, A.*; PETANIDOU, T.; TSCHEULIN, T.; GONZALEZ, V. H. ; HRANITZ, J. M. ; AGOSTO, J. ; BARTHELL, J. F. ; University of Maryland, Baltimore County , University of the Aegean, Mytileinei, GREECE, University of Kansas, Lawrence , Bloomsburg University of Pennsylvania , University of Puerto Rico, Rio Piedras , University of Central Oklahoma, Edmond ; *afernan1@umbc.edu*
Pollen Dynamics of Field Bindweed and Competitive Release in Pollen Loads of a Generalist Pollinator in the Mediterranean
Convolvulus arvensis, field bindweed, is common in Mediterranean climates but we know little of the pollen dynamics of this flower. We studied the pollen dynamics of the flowers, and the pollinator's foraging behaviors and foraging hours. We also studied how competition impacted pollen dynamics for *Lasioglossum malachurum* when the specialist competitor *Systropha curvicornis* was removed and present. For natural pollen decay, 10 flowers were monitored hourly and the anthers harvested for the pollen. *C. arvensis* pollen reward decayed rapidly from 6am to 9am and plateaued at about 10am, after visitation by early pollinators. Pollen dynamics and visitation show that, while *S. curvicornis* is a specialist, abundant *L. malachurum* remove most of the pollen during early foraging hours. To evaluate the *C. arvensis* pollen niches of the two bees, two sites were studied: one at which *S. curvicornis* was removed and one at which *S. curvicornis* was present. We collected 15 *L. malachurum* every hour from 7am to 9am, and their pollen was extracted and counted under a microscope. At the site with the competitor *S. curvicornis* present, the percentage of *C. arvensis* pollen on *L. malachurum* decreased at 9 am, when *S. curvicornis* foraging peaked on the flowers. Where the competitor was removed, *C. arvensis* pollen on *L. malachurum* remained high and constant throughout sampling. The two species display temporal niche partitioning of pollen by *C. arvensis*, for which the specialist *S. curvicornis* is a strong competitor against the generalist *L. malachurum*.

S1-4 FERNANDEZ-VALVERDE, Selene L.*; DEGNAN, Bernard M.; Unidad de Genómica Avanzada, Laboratorio Nacional de Genómica para la Biodiversidad (UGA-LANGEBIO), CINVESTAV, Irapuato, Guanajuato, Mexico, School of Biological Sciences, University of Queensland, Brisbane, Australia ; *selene.fernandez@cinvestav.mx*

Early evolution of gene regulatory networks in metazoan development.

Precise control of temporal and spatial developmental gene expression is critical to animal multicellularity. Early diverging animals possess most known families of animal transcription factors. However, little is known about the preservation of developmental gene regulatory networks (GRNs) that emerged along with metazoan multicellularity. Sponges share a similar gene composition with other animals, including genes crucial to the identity of tissues sponges lack such as neurons and muscles. The emergence of such genes and their regulators soon after or concomitantly with metazoan multicellularity suggest that metazoan (animal) morphological diversity and complexity are primarily driven by gene regulatory innovations. We have characterized the evolution of regulatory elements and the transcriptional repertoire in the marine sponge *Amphimedon queenslandica*, revealing a highly gene dense genome with short introns, UTRs and alternative splicing patterns resembling those of unicellular eukaryotes. *Amphimedon* also possesses almost 3,000 lncRNAs and evidence of bidirectional transcription at gene promoters, both of which might be carrying out similar regulatory functions as those found in bilaterians. Gene co-expression analysis across *Amphimedon* development reveals 23 co-expressed gene modules enriched in specific biological functions, with tightly regulated expression patterns that precisely coincide with ontogenetic transitions. The preservation of co-expressed gene modules, transcription factors and epigenetic control elements in *Amphimedon* and other animals allows for the identification of conserved features of the first metazoan GRNs.

113-3 FERRIS, K.G.*; BALLINGER, M.; HEYER, G.; PHIFER-RIXEY, M.; BI, K.; SUZUKI, T.A.; NACHMAN, M.W.; UC Davis, UC Berkeley, Monmouth University; *kgferris@ucdavis.edu*

The genetic basis of adaptation to extreme climates in house mice across the Americas

The house mouse, Mus musculus domesticus, colonized the Americas in conjunction with early European settlers 200-400 years ago. Since their arrival, house mice have rapidly expanded their range and now occur in a variety of novel and extreme habitats from Alaska to Tierra del Fuego making them an excellent system for identifying loci that underlie rapid environmental adaptation. We have collected tissue, phenotypic data, and live mice from latitudinal transects across North and South America that vary dramatically in temperature, precipitation, and seasonality. We find phenotypic clines in several adaptive traits including body size and coat color. In order to examine genetically based phenotypic differences in behavioral and physiological differences involved in environmental adaptation, we collected live mice from populations at the extremes of these transects and bred them in a common laboratory environment for five generations. Among other interesting differences, we find that cold adapted mice from New York & Canada build bigger nests and are more active than Tucson, Florida, & Brazil mice. To identify the genetic basis of environmental adaptation in house mice we use both population genomic and quantitative trait locus (QTL) mapping approaches. We find that exciting candidate genes involved in processes such as osmoregulation, energy metabolism, and circadian rhythms are under selection. Therefore we conclude that despite their recent introduction to the Americas, house mice have undergone rapid genetic diversification and adaptation to novel climates.

110-6 FETKE, JK; University of Cincinnati; *fetkeje@mail.uc.edu*

Characterization of the gene expression profile of ER alpha and Vitellogenin in the Fathead Minnow: implications for population effects

Estrogens, common contaminants in wastewater effluent, are endocrine disrupting compounds found to be potentially problematic for vertebrates. One of the more potent synthetic estrogens present in water systems is 17α-ethynylestradiol (EE2), an active ingredient found in many types of birth control. Estrogens stimulate the synthesis of vitellogenin (*vtg*), a precursor egg yolk protein, produced in egg laying vertebrates including fish. Additionally, estrogens are involved in the activation of intracellular estrogen receptors (ERs). ERs interact with estrogen response elements involved in the regulation of estrogen-responsive genes, such as *vtg*. Because of the inducibility of *vtg* expression upon exposure to estrogenic compounds, the *vtg* gene functions as a biomarker for exposure to environmental estrogens. This study characterizes the expression profile of two genes known to be responsive to estrogens, estrogen receptor alpha (*ERa*) and vitellogenin (*vtg*), in fathead minnows (*Pimephales promelas*) for both immediate and depurated time points. Fish were exposed to EE2 at concentrations of 0, 2.5, and 10 ng/L for 48 h. Gene expression was quantified across two tissue types: liver, where both genes are expressed, and brain, where *ERa* expression occurs but *vtg* expression does not. In liver, mean gene expression values for both *ERa* and *vtg* increased with exposure to higher EE2 concentration while their variances decreased. With increasing dosage, correlation between *ERa* and *vtg* expression increased.

126-4 FEY, SB*; VASSEUR, DA; LOGAN, ML; ALUJEVIC, K; O'CONNOR, MI; CLUSELLA-TRULLAS, S; Reed College, Yale University, Smithsonian Tropical Research Institute, Panama, Centre for Invasion Biology, Stellenbosch University, University of British Columbia; *feys@reed.edu*

Resolving Constraints and Opportunities for Behavioral Rescue in Response to Rapid Environmental Change

Behavior within the context of heterogeneous microhabitats is emerging as the primary mechanism by which ectotherms may avoid negative impacts of climate warming. However, the features of organisms and their environments that either constrain or enable effective behavioral thermoregulation remain poorly integrated into projections of future performance. As such, the degree to which behavior will actually ameliorate the negative fitness consequences of climate warming for wild populations is unclear. Here, we advance an approach for estimating field performance of ectotherms based on thermal reaction norms and the properties of the thermal landscape- including mean temperature, spatial variance, and spatial autocorrelation. We present a theoretical framework and explore its predictions, use this approach to examine the importance of behavior for a global dataset of 38 insect species using fine-grained climate projections, and lastly provide a case-study estimating historic and future performance of the subtropical lizard Agama atra. Our results show that integrating behavior and highly resolved environmental data into ecological forecasts can reduce or reverse the predicted detrimental responses of ectotherms to warming. However, the extent to which organisms are able to avoid such detrimental impacts largely depends on the relationship between mean environmental temperature and the cost of thermoregulatory behavior. For example, there is a strong positive relationship between mean temperature and thermal spatial variation in habitats occupied by Agama atra. This relationship suggests that the cost of thermoregulatory behavior will decrease as mean temperatures increase.

P2-260 FIELD, K; FORESTER, C; AUGUSTUS, A; MARUSKA, K*; Louisiana State Univ; *kmaruska@lsu.edu*

Effects of Maternal Care and Energetics on Neural Activation Patterns in the African Cichlid, Astatotilapia burtoni

Maternal care is essential across vertebrates and must be balanced with competing behaviors such as feeding. The underlying neural circuits regulating maternal care are described in mammals, but the mechanisms involved in switching from self-promoting to offspring-promoting behavior is poorly understood. The maternal mouth brooding cichlid *Astatotilapia burtoni* is an ideal system to examine the neural mechanisms modulating maternal care and feeding. Females undergo a period of forced starvation for ~2 wks after spawning while fry develop in the mouth. We compared neural activation patterns in females under three conditions: brooding, forced starvation, and fed, to examine which brain regions are involved in the conflicting motivational states of maternal care and energy balance. Brooding females were allowed to retain their brood for 12 days, while starved and fed females had fertilized eggs removed from their mouths and underwent either forced starvation or were fed for 12 days, respectively. Using the neural activation marker pS6, we found differential activation among female states in specific brain regions involved in maternal care and feeding. For example, brooding females had greater activation compared to fed and starved females in the ventral part of the ventral telencephalon and preoptic area, regions important for maternal care in mammals. Further, co-labeling for pS6 and *galanin* was observed in the preoptic area, highlighting a role for this region in maternal care and energetic circuits of fishes. Knowledge of which brain regions facilitate conflicting physiological and behavioral states is important for understanding the plasticity and evolution of neural circuitry controlling maternal care and feeding, with further important biomedical implications for eating disorders.

P2-39 FINERTY, CJ*; WARRINER, TR; HEATH, DD; SEMENIUK, CAD; LOVE, OP; University of Windsor, ON, GLIER University of Windsor, ON; *finerty@uwindsor.ca*

A Trancriptomics Approach to Examining the Effects of Pre-natal Cortisol and Increased Water Temperatures on Performance in Chinook Salmon (Oncorhynchus tshawytscha)

Global climate change is increasing water temperatures and impacting thermal-sensitive organisms living in these aquatic systems. Development under elevated water temperatures may alter offspring phenotype and ability to cope with these changes. In addition, maternal stress signals (such as pre-natal cortisol) may be an important mechanism by which offspring can prepare for a more stressful future environment. Here we take a transcriptomics approach to exploring the interactive roles of pre-natal stress and elevated water temperatures in influencing the capacity of fish to match developmental and physiological responses to future elevated water temperature stress in Chinook salmon (*Oncorhynchus tshawytscha*). To simulate a biologically relevant maternal stress signal, we will expose wild-collected eggs to one of two treatments immediately following fertilization: cortisol (1000 ng/ml) or control (water only) bath. Each group will then be subdivided into two temperature treatments representing current and climate-change projected (+3°C) water temperature regimes. Samples from relevant tissues will be collected across multiple life stages to examine transcriptional profiles across treatment combinations. To test whether pre-natal exposure to stress signals increases future preparedness to acute unpredictable stressors, we will examine the transcript responses of a subset of individuals to a water temperature spike. Overall this work represents an important first step towards determining whether exposure to pre-natal stress and temperature signals provides developmental plasticity and flexibility to adapt to projected temperature increases within climate change scenarios.

59-6 FINKLER, MS; Indiana Univ. Kokomo; *mfinkler@iuk.edu*

Exposure to fluctuating temperatures at different intervals during incubation influences embryonic growth and hatchling morphology in Chelydra serpentina.

Fluctuating diurnal temperatures influences incubation duration as well as the sex, size, and locomotor performance of hatchling turtles. However, given that different stages of development differ in their degree of thermal sensitivity, exposure to thermal fluctuations during some developmental intervals (e.g., early development) may have greater impact on hatchling phenotype than during other developmental intervals (e.g., late development). I incubated snapping turtle eggs under five different thermal regimes with the following combinations of constant temperature (25°C) and diurnally fluctuating temperature (25±2°C): constant temperature throughout incubation (Constant), fluctuating temperature throughout incubation (Fluctuating) and fluctuating temperature only during the first 21 days of incubation (1st Trimester) Days 22 to 42 (2nd Trimester), or from Day 43 to the end of incubation ("3rd Trimester") with constant temperatures at other intervals. Exposure to fluctuating temperatures accelerated embryonic growth and development rates compared to constant incubation temperatures at all intervals examined. Hatchlings from the Fluctuating treatment hatched earlier and had longer carapace and plastron lengths than did those from the Constant treatment or from the 3rd Trimester treatment. Eggs in the 1st Trimester treatment hatched sooner than did those in both the 3rd Trimester and Constant treatments. There was no difference in hatchling dry mass among any of the incubation treatments. These findings indicate that diurnal fluctuations in temperature accelerate growth and influence hatchling morphology. Moreover, fluctuating temperatures during early incubation appear to have a more pronounced effect on incubation duration than similar fluctuations during late incubation.

P1-138 FINNEGAN, D.*; SUMMERS, A.P.; BUSER, T.; KOLMANN, M.A.; Western Washington University, University of Washington- Friday Harbor Laboratories, University of Oregon; *finnegd@wwu.edu*

Convergence in Diet and Morphology in Marine and Freshwater Cottoid Fishes

Habitat transitions provide opportunities for drastic changes in ecology, morphology, and behavior of organisms. The goal of this study is to determine whether the numerous evolutionary transitions from marine to freshwaters have altered the pattern and pace of morphological and lineage diversification within the sculpins (Cottoidea). The broad global distribution and wide-ranging ecology of sculpins make them an ideal study system in which to analyze marine invasions in northern latitudes. The sheer diversity of sculpins in isolated systems like Lake Baikal has led some to suggest these fishes (particularly *Cottus*) underwent an adaptive radiation upon their invasion of freshwaters in north Asia and Europe. Marine sculpins appear to be more diverse than freshwater sculpins, and while cottoids show signs of explosive radiation early in their evolutionary history, our study shows that unequal patterns of clade disparity among these lineages has led to constant rates of morphological and lineage diversification. Feeding morphology traits are highly conserved in cottoids, with both marine and freshwater species displaying similar morphologies despite widely-varying diets. While convergence in feeding morphology and dietary ecology is widespread in freshwater and marine cottoids, some specialist taxa, including planktivores and piscivores, show notable departures from the ancestral sculpin body plan. These include planktivores like *Comephorus dybowskii*, as well as piscivores *Hemitripterus bolini* and *Myoxocephalus polyacanthocephalus*. *C. dybowskii's* unique feeding morphology, including a high posterior mechanical advantage and long dentary bones, may be further explained by its habitation of the pelagic environment.

113-7 FISCHER, EK*; SONG, Y; HUGHES, KA; ZHOU, W; HOKE, KL; Stanford University, Colorado State University, Florida State University; *efisch@stanford.edu*

Convergence, divergence, and connectivity in transcriptional mechanisms of repeated evolution

Recent research into whether independently evolved phenotypes share underlying mechanisms has provided examples of both extreme convergence and divergence in mechanisms. One implication of shared mechanisms contributing to parallel evolutionary transitions is the possibility that developmental or genetic constraints limit adaptation, whereas divergent mechanisms suggest that mechanistic flexibility facilitates evolution. We measured the extent to which shared transcriptional signatures evolve independently in Trinidadian guppies (Poecilia reticulata) adapting to common environments. We found evidence that a combination of consistent and unique transcriptional mechanisms contribute to similar adaptive phenotypes across parallel evolutionary events. In addition, we developed novel statistical methods to analyze whether patterns of connectivity among genes also evolve. We demonstrated that covariance structure among differentially expressed transcripts differ across populations, and that the distribution of connectivities among differentially expressed transcripts differs from that of non-differentially expressed transcripts. Despite inherent issues of non-independence of expression among genes within a network, transcriptional studies exploring changes in coexpression among genes are almost entirely lacking. Our results indicate that changes in patterns of connectivity among genes may play an important role in phenotypic evolution, and we suggest that transcriptional flexibility may facilitate rapid evolution during adaptation to novel environments.

134-7 FISH, FE*; MUTHUKRISHNAN, R; HAUSER, N; West Chester Univ., PA, Whale Research Centre, Cook Islands ; *ffish@wcupa.edu*

Fluke Flexibility during Propulsion in Neonate and Adult Humpback Whales

Oscillation of the flukes is the primary mechanism of propulsion by cetaceans. The flukes are composed of collagen fibers without any rigid skeletal elements. Small cetaceans, such as dolphins, have been shown to possess limited chordwise and spanwise flexibility in the flukes under load. The present study was initiated to determine the flexibility of the flukes in large cetaceans. The fluke oscillations of the humpback whales (*Megaptera novaeangliae*) were video recorded as the whales swam leisurely in the waters about Rarotonga in the Cook Islands. The fluke oscillations of adult and neonate whales were examined two-dimensionally from lateral views using ImageJ. To measure the degree of chordwise bending of the flukes, a Flex Index was calculated as ratio of the chord length to the camber line length, where a value of unity indicted no flexing. The largest amount of flexing was measured at the end of each half stroke with values for the Flex Index of 0.94 and 0.92, for the adult and neonatal whales, respectively. When the fluke is halfway between the extreme positions of the stroke cycle, the Flex Index was measured as 0.97 for both the adult and the neonate. The data indicate that there was effectively no difference in the flexibility between the flukes of adult and neonatal humpback whales. Despite the absence of rigid skeletal elements within the flukes, large cetaceans, such as the humpback whale, possess relatively stiff flukes when swimming. As the flukes of both small and large cetaceans exhibited similar degrees of flexibility, the stiffness of the flukes appears to be size independent.

7-1 FITAK, RR*; WHEELER, BR; SCHWEIKERT, LE; ERNST, DA; LOHMANN, KJ; JOHNSEN, S; Duke University, University of North Carolina; *rfitak9@gmail.com*

Candidate magnetoreception genes in the brain and retina of trout

Despite the prevalence of a magnetic sense among diverse taxa, little evidence exists for both the magnetoreceptor and the molecular mechanism responsible. There are currently two hypotheses: 1) light-dependent electron transfer in photoreceptive proteins and 2) interactions of magnetic particles (e.g., magnetite) with cells. In rainbow trout (*Oncorhynchus mykiss*), the availability of a genome sequence and a variety of behavioral and physiological evidence supporting the presence of magnetite-based magnetoreception make it an excellent model for molecular studies. In this study, we investigated the effects of a magnetic pulse on gene expression in the brain and retina of rainbow trout using next-generation sequencing. In the brain, we found that the magnetic pulse altered the expression of genes associated with iron-ion transport, such as the iron-sequestering protein *frim*, in addition to genes associated with the development and repair of photoreceptive structures (e.g. *crggm3, purp, prl, gcip, crabp1* and *pax6*). In contrast with the brain, gene expression both between and within the left and right retinae were unaffected by the magnetic pulse, thus suggesting a magnetoreceptor or mechanism located elsewhere. Taken together, our results demonstrated possible roles of iron-binding and trafficking proteins and non-visual encephalic photoreceptors in magnetoreception, and the potential for inadvertent effects of a magnetic pulse on processes unrelated to a magnetic sense. This study is the first to use genomic approaches to characterize magnetite-based magnetoreception in trout and contributes to our understanding of the molecular mechanisms of this enigmatic sense.

P1-161 FLEMING, C/G*; MCALISTER, J/S; College of the Holy Cross; *cgflem18@g.holycross.edu*

Examining the effects of timing of food exposure on the expression of feeding structure plasticity

Phenotypic plasticity occurs when an organism changes its phenotype in response to its environment with no concomitant change in genotype. A lag time between sensing the environment and phenotype production can occur when the environment is finely grained, i.e. when the environment changes faster than the organism can respond. Previous research has shown that marine invertebrate larvae can respond to changes in external food concentrations by altering the lengths of their feeding structures. Although most lab experiments of this phenomenon in echinoid larvae routinely only examine responses to absolute differences in the mean concentrations of food, previous research has demonstrated that organisms can cue on both the range (maximum and minimum) of food concentrations as well as the mean. What remains unknown, however, is how the timing of exposure to maximum or minimum food concentrations affects the expression of larval feeding structure plasticity. We reared larvae of *Lytechinus variegatus* under equal food means, but varying food maximums and minimums across a 12-day developmental period. By manipulating the point of development in which larvae receive the food maximum or minimum, we can understand how the timing of exposure to food and further, the environmental grain, are associated with feeding structure plasticity. Our preliminary observations suggest that larvae reared in coarse-grained environments (low or high) produce arms that correspond to the primary food level (long arms in low and short arms in high), whereas larvae reared in a fine-grained, fluctuating food environment produce arms that are intermediate in length. These results suggest that a lag time in the production of feeding structures may be associated with exposure to a fine-grained environment in this system.

101-4 FLETCHER, QE*; WEBBER, QMR; MENZIES, AK; COLLIS, M-A; WILLIS, CKR; University of Winnipeg; *q.fletcher@gmail.com*

The Evolutionary Potential of Hibernation Phenology in Little-brown bats

As global climate changes, animals must adjust the phenology of major life-cycle events to ensure that energetically costly activities coincide with peaks in resource abundance. It is assumed that an evolutionary response of phenological traits is required for natural populations to remain viable in response to climate change. We tested the hypothesis that hibernation phenology of little-brown bats (*Myotis lucifugus*) has evolutionary potential by quantifying the predictors and repeatability of hibernation phenological traits. Bats (n=6326) were outfitted with PIT-tags at five hibernacula in central Canada. PIT-tag dataloggers at the entrances of these hibernacula recorded the dates that bats immerged (i.e. entered) and emerged (i.e. departed) from hibernation. Immergence dates for males and females did not differ, and immergence date was not repeatable. Conversely, the emergence dates of females were 16 days earlier than emergence dates of males. For both sexes, emergence dates were significantly repeatable. For females, but not for males, individuals with larger masses emerged earlier from hibernation, presumably to facilitate earlier reproduction and offspring independence. In conclusion, our results place bat hibernation phenology into the context of life-history variation, whereas previously, bat hibernation was seen only as a energy saving mechanism.

56-7 FLIES, AS; FLIES, Andrew; University of Tasmania; *andy.flies@utas.edu.au*

Fluorescent recombinant proteins as a versatile solution for immunology in non-traditional species

Immunology research often focuses on quantification of specific cells types and molecules using monoclonal or polyclonal antibodies. A major limitation in ecoimmunology and wildlife immunology is the lack of species-specific reagents for non-traditional study species. The unprecedented success of checkpoint molecule (e.g. PD-1, CTLA-4) blockade in human cancer immunotherapy in recent years suggests that understanding receptor-ligand interactions is critical to understanding immune function. This talk will demonstrate how recombinant proteins were rapidly developed to characterize the Tasmanian devil immune system and the potential immune evasion pathways used by the devil facial tumor to subvert immune defenses. Fluorescently-tagged PD-1, CD80, 4-1BB, CD200, CD200R1, CD47 recombinant proteins were used to confirm that receptor-ligand interactions observed in humans and rodents are conserved in Tasmanian devils. Fluorescently-labelled recombinant cytokines, including IFN-γ, IL-2, IL-6, IL15- IL-21, TNF-α, and VEGFA were also produced. Initial testing demonstrated that Fluorescently-labelled IFN-γ can induce upregulation of MHC-I on devil facial tumor cells on par with unlabelled IFN-γ, suggesting that the fluorescent labels do not affect protein function. Ongoing testing will determine if these fluorescently-labelled cytokines can be used to map cytokine receptor expression. Following completion of our receptor-ligand studies, the recombinant proteins can be used to produce monoclonal or polyclonal antibodies for key proteins identified in the receptor-ligand studies. Importantly, these techniques can be quickly adapted to most eukaryotic species and allow unprecedented insight into the development and regulation of the immune system of non-traditional study species.

55-2 FLORES, DV*; JANZEN, FJ; Iowa State University; *dvflores@iastate.edu*

Epigenetic dimorphism and predisposition to sex under temperature-dependent sex determination

Vertebrates with temperature-dependent sex determination (TSD), a mechanism that relies on incubation temperature to determine irreversibly the sex of developing embryos, are especially threatened by the impending changes in climate. Though they have the same genome, males and females of species with TSD commonly have many dimorphic physical characteristics. Dimorphism may also extend to the molecular level, as regulation of genes involved in sex-specific characteristics may vary greatly. DNA methylation is an epigenetic modification well-known for its dynamic ability to silence genes in response to environmental triggers, including temperature. This study sought to characterize DNA methylation profiles between sexes across multiple life stages of a vertebrate with TSD, while also investigating its potential to predispose an embryo to develop into one sex over the other. We collected tissue from adults, hatchlings, and early-stage embryos of painted turtles, *Chrysemys picta*, to compare genome-wide DNA methylation of males and females at each stage. We followed this procedure by profiling candidate genes in the sex-determining cascade. Sexually dimorphic DNA methylation profiles were evident at all life stages. Additionally, embryos sampled from clutches that produced mostly one sex showed biased DNA methylation compared to embryos from clutches that produced mostly the opposite sex. Further epigenetic investigation of the TSD molecular mechanism will continue to unlock critical information previously cryptic in traditional genetic/genomic studies.

104-2 FLORIO, J*; FISHER, B; TSUTSUI, N; California Academy of Sciences, Univ. of California Berkeley ESPM; *Jflorio@calacademy.org*

Monitoring insect diversity in backyard swimming pools with citizen scientists

Citizen scientists represent a large and relatively untapped resource for studies of biological diversity, especially for groups like insects. Here we present the California Pools Project where participants collect insects trapped in their backyard swimming pools. This project has gathered thousands of research grade specimens while engaging participants about the biodiversity of their own backyards. Samples are collected monthly and show the phenology of trapped insects over the year. The collection represents 19 different orders with many of these taxa being vectors, pests and agriculturally relevant species. Additionally, many rare reproductive ants have been collected that were previously unseen in the region. The Pools Project is part of the NSF funded Backyard Biodiversity initiative to engage the public in the discovery and wonder of life in their own backyards.

P3-212 FODOR, ACA*; MAKABE, K; JEFFERY, WR; SATOH, N; SWALLA, BJ; Friday Harbor Laboratories and Biology Department, University of Washington, University of Tokushima, Tokushima, Japan, Station Biologique, Roscoff France, Okinawa Institute for Science and Technology, Okinawa, Japan; *zebinini@gmail.com*

The SHARK gene cymric is truncated in the ascidian Molgula occulta

Ascidians share several features with the vertebrates including pharyngeal slits, an endostyle, a notochord and a muscular tail. The molgulids are a monophyletic clade of ascidians in which a tailless phenotype has independently evolved multiple times. We are searching for the molecular basis of this tail loss by investigating the differential gene expression of *Molgula oculata* and *Molgula occulta*. *M. oculata* has the tailed larval phenotype, but *M. occulta* has lost their tail and sensory organs. The two species can be hybridized: if the eggs of the tailless species are used, then some of the resulting hybrids extend a half-tail and the sensory pigment cell is re-expressed. We have sequenced the genomes and developmental transcriptomes of these two species and the hybrid, and are searching for the mechanisms responsible for the loss of the ascidian tailed phenotype. We are investigating *cymric*, a SHARK tyrosine kinase located in the myoplasm in *M. oculata*. The tailed *M. oculata* makes the full *cymric* transcript, but the tailless *M. occulta cymric* transcript is missing the tyrosine kinase domain, suggesting that it is nonfunctional. Furthermore, the *M. occulta cymric* gene lacks the exons for the tyrosine kinase domain; making it one of the *M. occulta* genes on its way towards becoming a pseudogene, as has been shown for the tail muscle genes and the sensory pigment gene *tyrosinase*. We are investigating whether other tailless molgulid species also have an altered *cymric* gene, but our preliminary results suggest that the altered *cymric* is not the original mutation causing taillessness in molgulid ascidians, but rather a secondary effect observed in *Molgula occulta*.

105-8 FOKIDIS, HB; Rollins College; *hfokidis@rollins.edu*

Some order from chaos: systematic review and meta-analysis reveal an emerging framework for understanding steroid responses to energy challenges?

As signaling molecules, steroids can inform the body of impending changes in energetic state and facilitate a suite of metabolic, physiological and behavioral effects. Their vital roles in reproduction, stress and behavior means they are well-studied in both clinical and comparative disciplines, resulting in an enormous of data available comparing steroids across ranges of energetic challenges and measures. Traditionally, the different steroid classes have been associated with well-defined energetic effects, but a literature survey demonstrates highly variable and often contradicting results that may or may not support these roles. Thus aligning the traditional views relating energy and steroid functions have made developing a coherent framework difficult. I conducted an in-depth systematic review and meta-analysis of the comparative literature that relates steroids and energy (e.g., fasting, caloric restriction, and body condition). This review has demonstrated a significant discordance between: 1) manipulative studies and correlative research; 2) field and lab studies; 3) endotherms and ectotherms; 4) studies relating steroid levels to changes in body mass and those with changes in metabolic biomarkers; and 5) studies relating body condition with across varying steroid concentrations. Interestingly, mapping the effect sizes of energetic challenges against the variation in a respective steroid's concentration reveals a robust relationship that is only apparent beyond an inflection point. This suggests only steroids that exhibit a wide range of variation in concentrations within a population of interest will exhibit the traditionally defined energetic effect of steroids. I propose a new framework for investigating the relationship between steroids and energy that accounts for population-level variation in steroid concentration.

P3-193 FORD, KL*; ALBERT, JS; University of Louisiana at Lafayette; *klf8880@louisiana.edu*

The long and short of it: Patterns of snout differentiation in four species of electric fishes

In the weakly electric group of African fishes, Mormyridae, there is diversity in the head shape and snout length among the c. 221 species; however, the evolutionary and allometric patterns within this diversity are largely unstudied. Similarly, the group of weakly electric fishes from the Amazon, Gymnotiformes, require further study on the allometric growth patterns during development in the c.245 species. In both groups, some species have elongate tubular snouts with a small terminal mouth used for benthic feeding, while others use brachycephalic snouts to feed throughout the pelagic zone. This research analyzed patterns in snout elongation and head shape diversity in four species, two gymotiform species and two mormyridae species, using two-dimensional geometric morphometrics. Species included in this study have varying snout lengths, and include *Brienomyrus brachyistius* (n=29), *Mormyrops anguilloides* (n=14), *Porotergus duende* (n=27) and *Sternarchorhamphus muelleri* (n=15). Homologous landmarks were placed to capture the head shape, angle of snout depression, and snout length of the specimens. Through the *Geomorph* program, Principal Component Analyses of statistically significant variables were generated to perform multivariate regressions between the measurements of head shape diversity. Further, evolutionary allometry was analyzed to determine the covariation between shape and allometric growth among these species. These results showed significant covariation between head shape, snout length, and angle of snout depression among the adult specimens of the four species. This preliminary study provides further opportunities to evaluate the underlying the diversity of head shape among additional electric fish species and examine the covariation between snout elongation and ontogenetic patterns of diversification.

P3-264 FORSBURG, Z.R.*; GABOR, C.R.; Texas State University, San Marcos; *frog@txstate.edu*

Is artificial light at night a stressor for Rana berlandieri?

Artificial light at night (ALAN) is defined as artificial light that alters the natural light dark patterns in ecosystems. ALAN can have a suite of effects on community structure and is a driver of evolutionary processes that influences a range of behavioral and physiological traits. Effects of ALAN on amphibians is lacking and is important as ALAN could contribute to stress and declines of these populations, particularly in urban areas. We tested the hypothesis that exposure to constant light or pulsed light at night would physiologically stress leopard frog tadpoles *Rana berlandieri*. We exposed *R. berlandieri* to a natural light regimen, constant light, or pulsed light for 14 days. We used water-borne hormones to measure the amphibian stress hormone, corticosterone (CORT), release rates on days 2 and 14 of the experiment. Tadpoles in both light treatments and the control had suppressed CORT release rates on day 2 when compared to baseline levels of non-experimental tadpoles. By day 14, tadpoles in the control group and constant light treatment had CORT release rates similar to baseline levels while the CORT release rates of tadpoles in the pulsed light treatment remained suppressed. These results suggest that pulsed light at night is a chronic stressor for tadpoles whereas tadpoles habituated to constant light. This suggests that flood lights might have more negative impact on tadpoles then constant light, further investigation on additional effects such as foraging and response to predation and herbicides will help understand the impacts of ALAN on tadpoles.

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Fin and body neuromuscular coordination changes during walking and swimming in Polypterus senegalus

Muscle is responsible for an immense array of tasks essential to the function of all animals and integral to permitting vertebrate life to expand and diversify into virtually every niche. One of the most spectacular examples of niche expansion was the water-to-land transition, during which the evolution of terrestrial locomotion placed extraordinary demands on muscles accustomed to powering swimming. Recent work on *Polypterus,* basal ray-finned fishes that share many traits with stem tetrapods, has shown the importance of morphological changes to musculoskeletal structures for dealing with the locomotor challenges of terrestrialization. However, it is unclear how the neuromuscular control and coordination of their muscles differ during swimming and walking. We assessed muscle activity patterns of both the pectoral fin and body during walking and swimming in *Polypterus senegalus* using synchronized electromyography and three-dimensional high-speed video. Not only is motor unit recruitment greater during walking than swimming, but the timing of activity of the body muscles is shifted such that peak activity occurs closer to the time of peak body bending. Further, despite an increase in the absolute duration of muscle activity during walking compared to swimming, the proportion of the stroke during which muscle activity is present is smaller in walking than in swimming. Together these data suggest that there is a shift in the relationship between muscle activity and kinematics in walking *versus* swimming and that the muscles generate forces via more rapid, high-intensity bursts of activity to power walking compared to swimming. These data will significantly advance our understanding of how muscle function can be modulated to perform novel behaviours in the face of changes in demand.

54-1 FOSTER, JJ; RADFORD, AN; TEMPLE, SE; WILBY, D; ROBERTS, NW*; University of Lund, University of Bristol;
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The polarization of light as a feeding cue for fish

One of the outstanding questions in visual ecology is "Do vertebrates really use the polarization of light as a source of visual information?" The majority of evidence we have centers on teleost fish and electrophysiological measurements of polarization sensitivity. However, after almost 60 years of research, no strong evidence exists for any polarization informed behaviour. In other animals, behaviours that rely on the polarization of light fall into two categories, wide field tasks such as navigation, or spatial tasks such as visual signaling and communication. We have discovered that *Chromis viridis*, a common planktivorous reef fish, uses the polarization of light as wide field information, using a change in the degree of polarization as a feeding cue. Using a combination of on reef studies and controlled tank based experiments we find that as the polarization of light decreases, *Chromis* respond by leaving their home coral head, exhibiting a greater level of activity and feeding more. This change in polarization occurs naturally as the food load in the water column increases; the greater number of scatterers cause the degree of polarization to decrease. Furthermore, we show that this behavioural response is in part driven by ultraviolet wavelengths.

P1-169 FOUILLOUX, C*; GOYES VALLEJOS, J; TUMULTY, J; Univ. of Minnesota, Twin Cities, University of Connecticut, Storrs, CT ; *fouil001@umn.edu*

The effects of bromeliad water quality on the presence of golden rocket frog tadpoles.

Early life stages are often the most vulnerable, and parental decisions about where to deposit offspring are important determinants of offspring survival. This is particularly true of phytotelm breeding frogs, which deposit eggs and tadpoles in small pools of water in leaf axils. Eggs and tadpoles cannot move to different pools and are thus confined to the placement chosen by their parents. Predators and potential competitors seem to influence parental decisions, but the effect of abiotic characteristics of water quality on pool choice is unclear. We studied the golden rocket frog (*Anomaloglossus beebei*), a phytotelm breeder with parental care—which most notably exhibit the transportation of tadpoles from one pool of water to another. *A. beebei* live in giant tank bromeliads (*Brocchinia micrantha*), a species with leaf axils that retain water in large, stable phytotelmata. We analyzed water quality characteristics of over 100 bromeliad pools and examined how these conditions relate to the presence or absence of *A.beebei* tadpoles. We measured dissolved oxygen levels, turbidity, algae levels, photosynthetically active radiation, temperature, water volume, and leaf position. Tadpoles were not distributed randomly with respect to these variables. In particular, we found a positive relationship between dissolved oxygen level and tadpole presence; oxygen levels in pools containing tadpoles were never below 4 mg/L. While it is not clear if these characteristics directly affect pool choice, the non-random distribution of tadpoles suggests that adults prefer some pools over others for tadpole deposition. Furthermore, our study provides insight into the characteristics of important reproductive resources for this vulnerable species.

S5-2 FOX, JL; Case Western Reserve University; *jlf88@case.edu*

Cross-modal influence of mechanosensory input on visually guided behaviors in Drosophila

Animal behavior frequently requires the integration of information from multiple sensory modalities. In many moving animals, vision is a dominant modality, but visual information is only useful for movement in the context of the body's own position and motion. How do animals integrate visual motion with proprioception and mechanoreception to coordinate their movement? In flies (Diptera), specialized hindwings known as halteres detect body rotations and guide wing steering and head movements. We used quantitative behavioral analysis to examine how the fly nervous system uses visual and mechanical information to coordinate specific flight-related behaviors. Fruit flies (*Drosophila melanogaster*) were tethered to rigid pins and placed in the center of an arena consisting of several panels of LEDs. We measured the flies' wing steering and head movement behaviors in response to different visual stimuli, and compared the responses of flies with their halteres removed or glued to their thorax to the responses of intact flies. We noted that wing-steering responses to small moving figures were unaffected by haltere removal, but responses to moving wide-field stimuli were reduced when the halteres were glued or absent. Movements of the head were affected by haltere removal at higher speeds: though haltereless flies were still capable of following a wide-field stimulus with their gaze, they showed no amplitude modulation of the optomotor response in their head movements. Taken together, our data show that the influence of halteres on both wing steering and head movement behavior is dependent on behavioral and visual context. These results suggest a cross-modal role of haltere input on visually guided behaviors.

41-3 FOX, RA*; WESTNEAT, DF; Transylvania University, University of Kentucky; *rfox@transy.edu*
Corticosterone, Prolactin, Neophobia, and Behavioral Plasticity in Response to Brood Size Manipulations in House Sparrows (Passer domesticus)
Parental provisioning of offspring is a labile behavioral trait that is expected to be shaped by tradeoffs during the current breeding attempt and/or through residual reproductive value. Experiments have shown that parents can change their provisioning in response to changes in the number of offspring, the contribution of a partner, or effort and/or risks involved in providing care. What is less well understood is how these behavioral changes are mediated physiologically, though corticosterone (CORT; as mediator of behavioral plasticity, particularly in response to stress), and prolactin (PRL; which is known to affect parental care) seem to be likely candidate hormones. To test these ideas, we transiently manipulated brood sizes in nesting pairs of house sparrows when nestlings were 7-8 days old, collected measures of parental behavior before and after the manipulation, and took blood samples, which were analyzed for CORT and PRL, after parents had adjusted to the new brood sizes. While pairs with reduced broods decreased their provisioning rates, circulating CORT did not differ among unmanipulated pairs, pairs with increased broods, and pairs with decreased broods. However, birds with higher CORT provisioned less overall and decreased their provisioning more following the brood manipulation. Changes in parental behavior may be mediated by interactions with PRL or other hormones. Additionally, for a subset of pairs we measured behavioral and CORT responses to a series of novel objects presented at the nest during provisioning in order to test whether sensitivity to changes in offspring demand was associated with sensitivity to environmental changes in the broader sense.

37-5 FOX, T P*; HARRISON , J F; Arizona State University; *tpfox1@asu.edu*
Respiration is a one-way street: abdominal pumping induces unidirectional flow in beetles
While traditionally insect gas exchange is thought of as primarily diffusive, it has become increasingly clear that advective flow, sometimes uni-directional as in birds, supplements diffusion in most insects. Depending on the species and physiological conditions, gas exchange in insects can be mostly diffusive, tidally advective, or uni-directionally advective either in the forward or backwards direction, but the mechanisms and consequences of such variation are poorly understood. We measured CO_2 emission rates and unidirectional flow for adult *Zophobas morio*, the giant mealworm beetle, using a latex membrane to separate the mesothoracic spiracles and the subelytral abdominal spiracles into two separate respirometry chambers. In these beetles, the abdominal spiracles open into the subelytral space, so inhalation from this space is likely to increase the humidity of inhaled air. 90 percent of the animals displayed strongly unidirectional flow, with significantly more CO_2 being emitted in one direction, and such patterns were usually consistent over 24 h of measurement. However, whether the flow was forward or backward 90 percent of the recordings displayed unidirectionality. Females expelled most CO_2 via the mesothoracic spiracles, while males expelled most CO_2 via the abdominal spiracles, suggesting that morphological or physiological differences associated with sex affect direction of flow. Removal of the elytra was associated with increased CO_2 output via the mesothoracic spiracles, suggesting that alteration of subelytral conditions or desiccation (higher in animals with elytra removed) affect the direction of flow. These findings suggest that the direction of unidirectional flow is under physiological control, possibly in response to water balance or to reflect tissue-level variation in metabolism. This research was funded by NSF IOS 1558052.

P2-170 FRANCE, LA*; TAYLOR, GK; University of Oxford; *lydia.france@zoo.ox.ac.uk*
Mechanics and Guidance of Avian Perching Flight
Perching, or landing on a specific object, is performed very frequently by flying birds. Perching is a risky flight manoeuvre as errors could lead to death or severe injury in the event of an uncontrolled collision. Two main challenges arise during perching; sufficient aerodynamic braking prior to contact, and accurate flight guidance to the target. The mechanics of perching flight were studied from a perching Steppe eagle (*Aquila nipalensis*) to understand morphing wing kinematics during rapid-pitch up and stall, and quantify the high dissipation of energy during aerodynamic braking. Data was taken from reconstructed points tracked using photogrammetric techniques (Carruthers et al., 2010) across the wings, tail, and body. Novel techniques using motion capture with Harris Hawks (*Parabuteo unicinctus*) could provide greater insight into wing morphing during flight manoeuvres, and provide valuable insight for bio-inspired flapping UAVs. The flight control of perching flight was investigated using wild passerines (*Parus major*) recorded during perching flight to a fixed and moving perch. Flight trajectory variability and feedback during flight control were investigated to understand how sensory feedback is used during targeted flight in a variable and changing environment.

S6-3 FRANCIS, CD*; HORMONEBASE CONSORTIUM, ; FRANCIS, Clinton; Cal Poly, San Luis Obispo, www.hormonebase.org; *cdfranci@calpoly.edu*
Metabolic scaling of stress hormones across birds and mammals
Glucocorticoids are stress hormones that can strongly influence physiology, behavior and an organism's ability to cope with environmental change. Despite their importance, and the wealth of studies that have sought to understand how and why glucocorticoid concentrations vary within species, we do not have a clear understanding of how glucocorticoids vary across species and with respect to species traits. New research has proposed that much interspecific variation in glucocorticoid concentrations can be explained by variation in metabolism and body mass. Specifically, glucocorticoid concentrations should vary proportionally with mass-specific metabolic rates and, given known scaling relationships between body mass and metabolic rate, should scale to the -0.25 power of body mass. Here, we use HormoneBase, the newly compiled database that includes body mass data and plasma glucocorticoid measures from wild and un-manipulated vertebrate animals, to evaluate this hypothesis. Specifically, we explore the relationship between body mass and baseline cortisol or corticosterone in mammals and body mass and baseline corticosterone in birds. Our phylogenetically-informed models suggest that, while glucocorticoid concentrations do decrease with mass, the scaling exponents were significantly different from the -0.25 power proposed in recent research. Presently, we are exploring whether and how life history stage, sex and sampling method influence the mass-glucocorticoid relationship. Whether inclusion of these covariates reveals a universal-scaling exponent between glucocorticoids and mass or not, our study demonstrates how large-scale comparative methods can be a powerful approach to testing both long-standing and new questions in biology.

91-4 FRANK, CL*; INGALA, MR; BEGLIN, LJ; HUDSON, AJ; NISHAT, N; Fordham Univ., American Museum of Natural History; *frank@fordham.edu*

The Effects of Cutaneous Wax Esters, Triacyl- and Monoacylglycerols on the Susceptibility to White-nose Syndrome

White-nose Syndrome is caused by cutaneous infection with the fungus *Pseudogymnoascus destructans (Pd)*. It produces high hibernation mortality in 4 bats: *Myotis lucifugus*, *M. septentrionalis*, *M. sodalis*, and *Perimyotis subflavus*, but not in *Eptesicus fuscus*. The epidermis of *E. fuscus* contains 3 free fatty acids (FFAs) that greatly inhibit the growth of *Pd*: palmitoleic (16:1), oleic (18:1), and linoleic (18:2) acids. The epidermal lipids of bats also contain wax esters, monoacyl-, and triacylglycerols. We therefore predicted that: 1) epidermal monoacyl- and triacylglycerols containing these fatty acids reduce *Pd* growth, and, 2) epidermal wax esters containing these fatty acids also inhibit *Pd* growth. Laboratory culture experiments with *Pd* maintained on media varying in lipid composition were conducted. We observed that triacylglycerols have no effect on *Pd* growth, but 1-oleoglycerol greatly reduced *Pd* growth. We also found that wax esters containing 18:1, 16:1, and 18:2 all profoundly inhibit *Pd* growth more than the corresponding FFAs. Multiple epidermal lipids classes therefore influence the susceptibility of bat species/populations to infection with *Pd*.

111-6 FRECKELTON, ML*; NEDVED, BT; HADFIELD, MG; University of Hawai'i at Mānoa; *marnief@hawaii.edu*

Searching for the mechanism: enzymatic interrogations of outer membrane vesicles involved in the metamorphosis of Hydroides elegans (Polychaeta)

Bacterial biofilms are required for the induction of settlement and metamorphosis of many benthic marine invertebrates. The identity of the cues that mediate these interactions, however, remain largely unknown. The marine polychaete worm, *Hydroides elegans*, is one organism whose larvae settle and metamorphose in response to specific bacteria and bacterial products. Recently, we determined that one of the bacterial cues capable of inducing settlement in this species is outer membrane vesicles produced by the bacterium *Cellulophaga lytica*. Outer membrane vesicles are proteoliposomes produced ubiquitously by Gram-negative bacteria, and seem to be particularly prevalent in strains that associate with Eukaryotes. OMVs are composed of proteins, phospholipids, lipopolysaccharide, and occasionally genetic material and/or virulence factors. Among biological processes associated with OMVs are: cell-cell signalling; antibiotic resistance; virulence; and horizontal gene transfer. The mechanisms underlying these functions, however, are poorly understood. As a first step in determining how OMVs induce metamorphosis, OMVs were subjected to a range of enzymatic tests including DNase, RNase, protease and lipase treatments. Enzyme-treated OMVs were bio-assayed for metamorphic activity to determine which component of these complex delivery systems is involved in inducing metamorphosis of *H. elegans*. These experiments are ongoing; ultimately, the information they provide will be essential to understanding chemical cueing by bacteria in the larval metamorphic process.

55-3 FREDERICH, M*; LOGAN, L; Univ. of New England, Biddeford; *mfrederich@une.edu*

Population-specific morphology, behavior, and stress tolerance in the invasive green crab, Carcinus maenas

The European green crab, *Carcinus maenas*, is a globally invasive species with highly detrimental effects on invaded ecosystems. Molecular techniques have recently allowed to reconstruct the invasion history of this species and have shown that distinct genetically different as well as hybrid populations exist. We compared crab populations collected in Iceland (part of the native range), Maine (from the invasion in 1817), and Newfoundland and Nova Scotia (hybrids between Maine and a second invasion in the 1980s into Canada) for morphology, behavior, and stress tolerance. *C. maenas* from different regions displayed varied carapace morphology in a 3D shape analysis of homologous morphological points. Nova Scotian crabs were significantly more aggressive than all other populations. However, no differences were found in claw crushing force. When *C. maenas* were placed into a 5 m diameter mesocosm of eelgrass the hybrid populations, NS and NL, destroyed more plants than other populations. During a low salinity exposure (10 ppt, 72 h) many crabs from Iceland died, or showed significantly reduced motor performance compared to the other populations. Differences in gene expression of cellular stress markers and NaK-ATPase were observed after the salinity exposure. These results highlight key differences between the native, invasive, and hybrid populations. Therefore, behavior, morphology, and physiology of this species need to be considered as distinct traits between different populations and might reflect adaptations to the respective new habitat. Currently, the hybrid population from Nova Scotia is extending southwards into Maine and will most likely create even more damage to an already *C. maenas*-damaged ecosystem, due to its superior aggression and destructiveness.

14-8 FREDERICK, AR*; FREIDMAN, CS; GERMAN, DP; University of California, Irvine, University of Washington; *alyssa.frederick@uci.edu*

Withering-syndrome induced gene expression changes in pinto abalone, Haliotis kamtschatkana

In the abalone and *Rickettsiales*-like organism (RLO) system, the RLO infects abalone digestive tissues and leads to extreme starvation and a characteristic "withering" of the gastropod foot. First identified in black abalone in California after an El Niño event, the withering syndrome-causing RLO (WS-RLO) has been seen in various sites around the world, and has been found in at least low levels in all abalone species examined. Some abalone species appear to be highly resistant to the disease, unless held at extremely high temperatures. This suggests that the resistant species possess some physiological resistance to the effects of high temperature. Our goal is to develop a detailed understanding of the abalone digestive system and the mechanisms for differential resistance across the *Haliotis* (abalone) genus. We examined baseline differences in gene expression in pinto abalone (*Haliotis kamtschatkana*) between infected and uninfected individuals. Pinto abalone were infected with the WS-RLO and sampled over 7 months. We used RNAseq to identify the genes being differentially expressed between the two groups. Gene expression differences between infected and uninfected animals will be compared and unique genes between naïve and infected abalone will be compared using heat maps generated in R. Statistical analysis will distinguish genes showing differential expression responses between species. With this data, we are identifying gene expression patterns in abalone digestive tracts that lead to WS expression during RLO infection.

45-6 FREEMAN, NE*; NORRIS, DR; STRICKLAND, D; NEWMAN, AEM; University of Guelph, Ontario, Retired Chief Park Naturalist, Algonquin Provincial Park, Ontario; *nfreeman@uoguelph.ca*

Carry-over Effects of Early-life Food Availability on Stress Physiology and Survival: A Supplementation Experiment in a Winter Breeding Passerine

Environmental conditions during early-life play a vital role in the development of an individual's hypothalamic-pituitary-adrenal (HPA) axis but how these conditions carry-over to influence stress physiology, behavior and survival in natural systems is poorly understood. We examined the hypothesis that food quantity in early-life influences short and long-term HPA axis activity and survival by quantifying feather corticosterone, body condition, and fledging date in young grey jays (*Perisoreus canadensis*). In 2017, 10 pairs of breeding adults were supplemented with high protein and high fat food throughout the nestling period while 9 pairs were un-supplemented controls. Individuals from supplemented territories were in better condition at 14 d and left the nest, on average, 6 d earlier. We will also present rates of survival and data on HPA axis activity during the nestling and fledgling stages using feather corticosterone analysis of tail feathers collected from independent juveniles at ~200 d of age. Our preliminary study highlights the vital role ecophysiological factors during development, such as food availability, play in mediating stress physiology and survival.

S10-7 FRENCH, SS*; SMITH, GD; HUDSON, SB; DURSO, AM; Utah State University, Dixie State University; *susannah.french@usu.edu*

Town and Country Reptiles: Physiological Trade-offs Across a Changing Landscape

A little lizard can say a lot about the health of an environment. Disturbances in an animal's environment, including anthropogenic change, can affect how it acquires and uses limited energy resources to respond to stress, reproduce, and fight disease. Urbanization is one of the major forms of anthropogenic disturbance facing wild populations today. To better understand how urban changes affect animals in nature, we are using a variety of methods to track, monitor, and experimentally manipulate a well-studied model organism, the side-blotched lizard. A synthesis of physiological, demographic, and genomic results will be presented from a combination of field and laboratory studies to test both individual and population-level responses to urbanization. We are working to answer these questions which will help provide a broader picture of how species respond and even adapt to environmental change.

P3-98 FREUND, DR*; MURPHY, TG; Trinity University; *dfreund@trinity.edu*

The effect of testosterone on dominance and status signaling in the female American goldfinch (Spinus tristus)

Elaborate traits often serve as honest signals of aggression and fighting ability or motivation to potential competitors. Historically, studies on such traits have focused on the more aggressive male sex. However, the American goldfinch *(Spinus trusts)* is unique in that females exhibit an orange bill, which serves as a dynamic carotenoid-based status signal to mediate aggressive interactions over food resources. Although testosterone (T), a hormone well known to mediate aggression in males, is known to affect female aggression in some species, the relationship between female aggression and T appears to vary between species, and the link between this hormone and female contest behavior is not fully supported. The unique relationship between bill color and aggressive outcome in American goldfinches appears to be limited to females, as a similar hypothesis was not supported for male bill color. This suggests a unique sex-specific divergence of ornamental function, and the potential for T to play a different role in mediating bill color between the sexes. In this study, the effects of T on both dominance and bill color of female American goldfinches was analyzed. Female birds were administered T or control treatments via subcutaneous injections for 5 subsequent days. On the fifth day, birds novel to each other were placed into dyads after being deprived of food to analyze dominance. T was administered so that each in each dyad a T bird was competing against a control bird. Winners were determined as the individual that won at least 80% of the supplants and hold-offs at the feeding station. T plasma levels and spectrometer measurements of bill color were taken before and after T administration to determine the influence of T on rank and bill color. Analyses will reveal if dominance and bill color were greater in the T-augmented females compared to the control females.

18-4 FRIEDMAN, ST*; PRICE, SA; WAINWRIGHT, PC; Univ. of California, Davis, Clemson University; *sarahtfried@gmail.com*

The Influence of Body Size on Morphological Diversification Across Fishes

Understanding the diversity of body shapes across the tree of life is one of the central challenges in evolutionary biology. One potential mechanism of generating morphological diversity is the strongly conserved allometric relationship between size and shape. By altering body size, species undergo predictable changes in morphology, promoting phenotypic differentiation. Evolutionary changes in size have been shown to account for a large fraction of variation in facial morphology across small mammals (40% in squirrels, 38% in bats, 33% in mongooses) and almost 80% of shape variation in raptor beaks. Here, we quantify the amount of shape evolution attributable to changes in body size across nearly 800 species of teleost fishes. Using a phylogenetic framework, we analyze 17 geometric morphometric landmarks positioned to capture general body shape and functionally-significant features. In marked contrast to the vertebrate lineages noted above, we find that changes in body size only explain 11% of the morphological variation seen in teleost fishes. These findings suggest that morphological diversification in fishes is largely independent of body size. Furthermore, the role of body size in accounting for the evolution of body shape varies considerably among fish families, ranging from 6-50% of shape variation explained by size. Complexity in the relationship between size and shape across families may, in part, explain the immense morphological diversity seen in teleost fishes.

11-7 FUESS, LE*; PALACIO, A; BAKER, AC; MYDLARZ, LD; University of Texas at Arlington, University of Miami; *fuess@uta.edu*

Frenemies: Symbiodinium density negatively affects immune response in the Caribbean coral Orbicella faveolata

Scelaractinian corals form the basis of one of the most diverse ecosystems on the planet, coral reefs. However recently these ecosystems have been in decline due to die offs of corals as a result multiple stressors, including increasing sea surface temperatures, disease outbreaks and nutrient enrichment. Corals are dependent upon symbiotic dinofagellates, *Symbiodinium*, for their nutritional needs. Despite this, theory suggests that *Symbiodinium* may suppress host immunity to maintain symbiosis. To explore the consequences of symbiosis on host immunity, we conducted an experimental manipulation of symbiont density using nutrient enrichment. Cores of the Caribbean coral *Orbicella faveolata* were pre-treated with nutrient enrichment for one month to increase symbiont density. Following this period both nutrient enriched and control corals were exposed to immune challenge using a mixture of lipopolysaccharides and Poly I:C. Following the experiment, samples were analyzed using RNAseq and symbiont density was quantified using qPCR. Analysis of host gene expression revealed different effects of nutrient enrichment and symbiont density. As expected, increases in symbiont density appeared to have a negative effect on host expression of immune-related transcripts. In contrast, nutrient enrichment alone, and in combination with immune challenge, increased expression of several putative immune transcripts. Our results suggest an important ecological trade-off for corals: while increased symbiont density may provide an energetic benefit to the host, this likely comes at the cost of reduced host immunity. Further study of this trade-off is essential to understand the potential consequences of increasing disease prevalence on reef ecosystems.

P2-44 FULLER, RG*; ROMERO, LM; Tufts University; *rory.fuller@tufts.edu*

Correlations between temperature, glucocorticoid levels, and post-captivity escape behavior in the eastern painted turtle, Chrysemys picta picta

Glucocorticoid hormones form an important part of the vertebrate response to stressful situations, affecting to some degree almost every tissue in the body. Their effects manifest both physiologically and behaviorally, with many animals displaying elevated motility or other evasive behaviors in concert with elevated hormone levels. Much of the research on this topic, however, has been performed in mammals and birds. Ectotherms present a more complicated picture, as their flexible body temperatures have been shown to cause changes in glucocorticoid secretion rates and modifications to behavioral responses. It is therefore critical to evaluate how the physiological response of an ectothermic species of interest varies under different temperatures, and how this correlates with behavior. Therefore, as part of a larger field study, turtles were captured and their blood was assayed for glucococorticoid levels, along with measurement of associated body temperatures. Timing of various escape behaviors following release onto the shore at their capture site was recorded for the animals. We present the initial results from our first season of investigation of these inter-linked phenomena.

P3-273 FUNK, A*; WILLS, N; PINSKY, B; MINICOZZI, M; MASS, S; SUNY New Paltz, Northern Arizona University; *alfunk826@gmail.com*

Disrupting Microtubule Polymerization in Regenerating Planaria

The known xenoestrogen Bisphenol-A (BPA), has profound effects on planarian regeneration. Prior work in our lab has shown that BPA can depress and delay regeneration in a variety of flatworms at high doses and stimulate regeneration at very low doses. Since regeneration involves both proliferation and cell movement, we hypothesized that cytoskeleton may be one of the mechanisms by which endocrine disruptors are affecting regeneration in flatworms. In this work we compare the effects of Paclitaxel, a microtubule polymerization inhibitor, to BPA to determine if the regenerative phenotypes are similar.

98-2 FUNKHOUSER, C*; WALSH, M; Univ of Texas at Arlington; *collin@uta.edu*

Effects of flow regimes on morphology and swimming performance

Understanding the evolutionary trade-offs is important in predicting how species will respond to changing habitat conditions. The gulf killifish (*Fundulus grandis*) is native to the Gulf of Mexico but has been introduced in several rivers across North Texas. We evaluated patterns of selection on whole organism morphology in current and historical populations of *Fundulus* across its native range as well as introduced populations in inland freshwater rivers. Using landmark morphometrics, we found body shape differences between rivers and coastal sites, with river populations exhibiting body shape associated with unsteady swimming performance. We also found differences across time, where the earliest specimens from introduced sites more closely resembled coastal sites, showing that body shape in the current populations has diverged from the coastal ancestor. To understand what affect this had on performance, we also performed swimming performance assay to determine how body shape affected swimming ability. We found, consistent with our predictions, that fish from habitats with flowing conditions had more streamlined (unsteady) morphologies, and better swimming performance, than fish from populations with little/no flow. Ultimately, our results show how gross morphology is shaped over time in response to shifts in flow regimes.

S6-5 FUXJAGER, M.J.*; MILLER, E.T.; HORMONEBASE CONSORTIUM, ; Wake Forest Univ., Cornell Univ., www.hormonebase.org; *fuxjagmj@wfu.edu*

Macroevolutionary Patterning of Androgen and Glucocorticoid Levels Across the Vertebrate Phylogeny

Biologists have long recognized that circulating steroid levels vary significantly both among different species and within individuals of the same species. This observation often leads to the assumption that steroid levels themselves are "hypervariable traits," which can easily evolve in response to a variety of factors. This idea, however, is seldom explored in a rigorous manner, especially when it comes to charting out the evolutionary trajectory of a circulating steroid across the vertebrate tree of life. Using data derived from HormoneBase, a data set that collates steroid hormone levels of hundreds of fish, reptile, amphibian, mammal, and bird species, we model how changes in selection regimes across the vertebrate phylogeny describe the evolutionary patterning of circulating androgen and corticosterone in both males and females. In males, we find that mammals, birds, and most fishes have shifted to new evolutionary regimes, and exhibit lower levels of testosterone or 11-ketotestosterone than the inferred ancestral vertebrate evolutionary regime (to which crocodiles, turtles, squamates, and amphibians belong). However, in females, we infer no shifts in optimal androgen levels across the entire phylogenetic landscape. For glucocorticoid levels, both males and females experienced distinct and parallel regime shifts, in which all vertebrates, except for fishes, are inferred to have shifted to exhibit lower levels of these hormones, with a subsequent shift to higher levels in most mammals. Overall, these data show episodes of major taxonomic divergence in regime changes that set the trajectory of circulating steroid level evolution.

P3-181 GABLER, MK*; LOHR, AJ; KOOPMAN, HN; Univ. North Carolina, Wilmington; *mkg5178@uncw.edu*

How uniform are mammalian adipocytes? Adipocyte size in the blubber of odontocetes

Blubber is a modified form of lipid-rich adipose tissue that is unique to marine mammals. The many functions of blubber include the primary storage of energy, thermoregulation, streamlining and buoyancy. Because of the unique characteristics of blubber, it is interesting that studies on the morphology of the adipocytes are limited. Previous studies have shown that blubber adipocyte morphology differs between age class and reproductive state among bottlenose dolphin populations; however, we do not know how cell size varies across species. Using tissue that was fixed and embedded in paraffin, slides were stained using hematoxylin and eosin stain in order to determine the morphological differences between the adipose of deep and shallow-diving odontocetes. The families of odontocetes used in this study were the family Delphinidae, Kogiidae, and Ziphiidae. Pig adipose was used as a terrestrial mammal comparison. Adipocyte cell size and aspect ratio were measured. Cell size varied between the blubber layers of all individuals studied, with the smallest cells observed in the outer blubber layer and the largest in the inner blubber layer. Ziphiidae had adipocytes in all blubber layers that were 2-3 times larger than those compared to the other odontocetes and other mammals (i.e. elephant seals, rats and dogs). The adipocyte characteristics in pig fat were similar to the Delphinidae and Kogiidae adipocytes and other mammals, suggesting that most mammalian adipocyte size is conserved. These variations in morphological adipocyte characteristics suggest the potential for phylogenetic differences between odontocete blubber. Cell size may also be affected by the storage and mobilization of lipid in adipocytes, as microvessel differences have also been observed between species.

43-5 GAGLIARDI, S F*; COMBES, S A; GAGLIARDI, SUSAN; University of California-Davis; *gagliardi@ucdavis.edu*

May the wind not always be at your back: Bumblebees prefer to fly upwind

Bumblebees forage in windy, unpredictable environments where they must make decisions about how to reach certain resources. Wind conditions likely affect their flight paths and foraging efficiency. In natural environments, bees are often confronted with headwinds or tailwinds, yet little attention has been paid to whether bees choose flight routes based on wind direction. We allowed a colony of *Bombus vosnesenskii* to forage in a dual-channel wind tunnel with small fans in both channels, and with the nest box and nectar source at opposite ends. We altered wind conditions daily in the two channels and observed foraging behavior with no wind, with 1.25 m/s wind in opposite directions in each channel, or with 1.1 m/s wind in one channel and no wind in the other. We used two high speed cameras above the tunnel to collect 1.2 s of video per minute over two hours, for fourteen days. We tracked all bees in each video, providing us with the location, direction, and speed of each bee. Bees showed no preference for either side of the dual-channel wind tunnel. However, we found that bees exhibited a significant preference for flying upwind vs. downwind, choosing the channel that allowed them to fly upwind approximately twice as often. Flying upwind requires an increase in thrust production while a tailwind adds to the bee's forward speed, suggesting that downwind flight should be easier; but previous work has shown that bees can increase their forward speed with little metabolic cost, whereas they struggle to maintain stability when flying with a tailwind. Along with our findings that bees prefer to fly upwind, this suggests that maintaining stability is a major consideration for bees in flight, and that flying with a tailwind may be an overlooked flight challenge in natural, windy environments.

P1-75 GAGLIO, AE*; LOUDER, MM; HAUBER , M; LYNCH , KS; Hofstra University, Hunter College , Hunter College, Hofstra University ; *Annmariegaglio@gmail.com*

Creating a strong password: Understanding the neural basis of species recognition in brood parasites

Obligate avian brood parasites lay their eggs in the nest of a heterospecific host leaving juveniles without exposure to conspecifics during critical developmental periods. One mechanism by which these juveniles learn to recognize conspecifics is by using a password, typically an unlearned vocalization that cues species recognition. The purpose of the experiments presented here were to explore the neural basis of the password hypothesis as a mechanism of mis-imprint avoidance. We found that adult cowbirds, Molothrus ater, show greater expression of the activity dependent immediate early gene ZENK in two auditory forebrain regions, the caudomedial nidopallium (NCM) and the caudomedial mesopallium (CMM) in response to cowbird chatter relative to a heterospecific control. Juvenile cowbirds showed greater ZENK expression in response to chatter only within the NCM. Our second study also revealed that juvenile cowbirds have greater ZENK in CMM in response to song that was recently experienced, either heterospecific or conspecific. Thus, in juvenile male cowbirds there is early onset of species-specific selective neural representation of non-learned calls in NCM and recently experienced song in CMM. These results suggest NCM was evolutionary co-opted to recognize the species-specific chatter whereas neural signatures of song memory (even heterospecific songs) reside in CMM.

P2-173 GAGNON, YL*; NILSSON, DE; Lund University;
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Could scallops have polarization vision?
Scallops, molluscs within the Family Pectinidae, are a group of swimming bivalves with dozens of surprisingly complex eyes. Their eyes include a cornea, lens, mirror, and two layered retinas: a proximal and a distal retina. The proximal retina is positioned well behind the focal point of the eye, receiving images that are significantly less focused than the images the distal retina registers (since the distal retina does lie at the focal point of the eye). Although the anatomy of scallops has been studied since the late 19th century, no one knows to this date why the eyes of scallops have two retinas. An astonishing difference between the two retinas is that the distal retina contains ciliary photoreceptors while the proximal retina consists of rhabdomeric photoreceptors. The proximal retina may therefore be sensitive to the polarization of light. Regretfully, not enough histological work has been done to ascertain if scallop rhabdoms have or do not have the ordered morphology required for spatial polarization vision. The possibility of polarization sensitivity in scallops is well worth the additional effort of a closer look because linear polarization is common underwater and could prove useful for scallop navigation and/or threat detection. I will therefore investigate the scallops' polarization vision by testing their response to a stimulus which contains only polarization contrast (i.e. an object that is identical to its background in spectrum and intensity but is different in the degree and/or angle of the linear polarization of the light).

108-1 GALL, MD*; BAUGH, AT; BEE, MA; GALL, Megan;
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The Difference a Day Makes: Effects of Oviposition on Peripheral Auditory Sensitivity
For many animals there are rapid physiological and behavioral transitions that occur when females oviposit. In many species of treefrogs gravid females actively search out and approach males based on the quality of their calls. Females preferences can be easily assessed using phonotaxis experiments. However, immediate after oviposition female responsiveness to male calls decreases dramatically and females will no longer respond to male vocalizations. In this study we asked whether there are concomitant changes in circulating hormone levels and the sensitivity of the auditory periphery to common elements of male vocalizations. In this talk I will discuss our surprising results that peripheral auditory sensitivity, in some cases, appears to increase following oviposition. It is not yet clear whether this difference is the result of hormonal changes affecting the periphery or whether changes in motivational state may influence background physiological noise and response to paralytics. Future work will focus on teasing apart these effects to understand the processes that mediate the dramatic behavioral changes that occur within the 24 hours in which oviposition occurs.

P1-271 GALLOWAY, K/A*; GRUBICH, J/R; PORTER, M/E;
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Puncture performance of red lionfish, Pterois volitans, spines on buccal skin from grouper, Mycteroperca bonaci
The red lionfish, *Pterois volitans*, has an array of venomous spines spaced among several fins (13 dorsal, 2 pelvic, 3 anal), which may contribute to their invasion success. Dorsal spines are long needle-like structures, while the pelvic and anal spines are shorter, more robust, and slightly recurved. Due to these structural differences, we predict puncture force will vary with spine morphology. Caribbean groupers have been documented to predate invasive lionfish and may act as a biotic control. Here we examine which lionfish spines are most effective as a defense system against black grouper by determining which spines can puncture skin with the least amount of force. We quantified the force required to puncture each grouper skin section for dorsal, pelvic, and anal spines using an Instron E1000. Black grouper, *Mycteroperca bonaci*, skin was dissected from the premaxilla, urohyal, and neurocranium. Like lionfish, grouper suction feeding behavior devours fish prey whole, including venomous spines. Sections of black grouper mouth skin were chosen to include skin that is likely to be in contact with lionfish spines during feeding events. Spines were placed in grips and the actuator punctured the spines into the skin at a rate of 10mm/min, which is a common speed used in puncture testing of fish scales and hypodermic needles. Puncture forces were averaged and compared between each buccal skin section and each spine region. These data will provide insight on a possible biological control, specifically if lionfish are capable of damage to predators such as grouper.

113-2 GAMBOA, MP*; SILLETT, TS; FUNK, WC;
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The Genomic Basis of Adaptive Phenotypic Divergence in Bill Morphology of Channel Island Song Sparrows
Populations may evolve fixed allelic differences in response to variation in selection regimes over geographic space and time leading to quantifiable patterns of adaptive phenotypic divergence. However, establishing the link between genotypes and phenotypes remains particularly challenging in natural populations. Genome-wide association (GWA) techniques provide an indirect method of understanding local adaptation of non-model organisms to natural systems by relating observed phenotypic variation among individuals to underlying genetic variation. Here, we use GWA methods to examine the statistical association between morphology and thousands of SNPs in song sparrows (*Melospiza melodia graminea*) distributed along a strong climate gradient on the California Channel Islands. Specifically, we related bill surface area, a trait that differs significantly between islands with different climates, and RAD-seq generated SNPs using single-locus and multi-locus models implemented in GenABEL and GEMMA. After aligning SNPs to the annotated-reference genome of a closely-related sparrow and controlling for population structure, we identified several SNPs significantly associated with bill variation. Most SNPs were found in genes, or closely-linked to genes, responsible for metabolic function and immune response, but some genes (e.g., SLCA1 and WCNT4) are also implicated in craniofacial development and binding of calmodulin, a pathway known to influence bill morphology in Darwin's finches. This suggests bill morphology is a complex trait controlled by multiple genes and provides further support for local adaptation to climate in Channel Island song sparrows.

P2-243 GANDHI, MP*; MACKAY, S; BERGMAN, D; San Jose State University, Grand Valley State University;
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Chronic Effects of Nonylphenol on Crayfish Aggression

Nonylphenol (NP) is a compound used as a surfactant in a variety of industrial, domestic, and agricultural products. NP is abundantly found in deoxygenated areas containing sediment, an ideal habitat for crayfish. It acts as an endocrine disruptor by mimicking estrogen, influencing the behavior of organisms like crayfish. Crayfish utilize aggressive behaviors to find food, mates, and establish social hierarchies. We hypothesize that crayfish will alter the frequency of aggressive behavior over extended periods of chronic nonylphenol exposure. To test this hypothesis, 60 male adult crayfish, Orconectes propinquus, were randomly separated into three treatment groups: high exposure (0.3 ng/L), low exposure (0.15 ng/L), and control (vehicle agent). To measure aggressive behavior, fight trials were conducted and recorded for subsequent analysis. During fight trials, crayfish were size matched to decrease any confounding effects of size. Interactions were later analyzed by observing the behavior of the pair of crayfish. We recorded the temporal mechanics by measuring fight intensity and duration of encounters. Preliminary results indicate changes in aggression intensity in nonylphenol exposed crayfish.

S6-6 GARAMSZEGI, LZ*; HORMONEBASE CONSORTIUM, ; Estación Biológica de Doñana-CSIC, www.hormonebase.org;
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Phylogeny and diversification: levels of glucocorticoid hormones and speciation rate in birds

Stress physiology may have consequences for species richness at macroevolutionary scales, because species that inhabit stressful environments would be favored to occupy and quickly adapt to new -and less stressful- habitats promoting species diversification. Furthermore, species that maintain broad within-species variation in stress response are more likely to have individuals that can successfully cope with unpredictable environmental challenges bringing them into new ecological niches than species with narrow within-species variation. We have tested these ideas relying on the HormoneBase repository, and investigated the relationship between baseline and stress-induced corticosterone levels and speciation rate in a phylogenetic study of birds. To estimate speciation rates, we applied Bayesian analysis of macroevolutionary mixtures that can account for variation in diversification rate among clades and through time. There was no evidence for either the mean of baseline or that of the stress-induced hormone levels being associated with the degree of speciation. The same observation was also held for the intra-specific variance of the traits and also when controlling for potentially confounding effects such as body mass or latitude. These results may imply that stress physiology plays a minor role in determining speciation rates in birds, because, for example, species in more- or less stressful environments are equally well-adapted and have equal probability of speciating.

28-6 GARCIA, MJ*; TEETS, NM; University of Kentucky;
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Neuromuscular Performance as Measures of Thermal Tolerance

Thermal tolerance is an important predictor of current species distributions, the potential to invade new environments, and species' responses to rapid climate change. There are many metrics available for measuring thermal tolerance, and each comes with its own benefits and challenges. For example, examining the effects of thermal stress on fecundity has clear ecological and evolutionary relevance, but it is labor intensive to measure. Conversely, metrics like critical thermal minimum temperature (CTmin) are high-throughput but are further removed from direct fitness consequences. Here we applied a novel assay, the Rapid Iterative Negative Geotaxis (RING) assay, to investigate sub-lethal effects of cold exposure in *Drosophila melanogaster*. The RING assay allows us to assess neuromuscular performance by quantifying the reaction time and climbing performance of groups of flies after cold stress. We exposed groups of flies to chilling conditions (0°C), and examined the extent to which exposure duration, recovery time, and cold acclimation prior to exposure influenced performance. Duration of cold exposure had a significant, negative impact on climbing performance, with reaction time increasing and rate of climbing decreasing as cold exposure increased from 2-24 h. However, following cold exposure of an intermediate duration (12 h), climbing performance gradually improved during recovery, with all flies regaining normal neuromuscular function within 48 hours of recovery. The final experiment assessing the impacts of cold acclimation on neuromuscular performance is currently in progress. Our results show that the RING method is a robust assay for non-invasively assessing sub-lethal cold injury and provides correlative, organismal evidence of ion homeostasis dysregulation as a possible mechanism underlying sub-lethal cold injury.

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Neuronal Plasticity in the Forebrain of the Male Checkered Garter Snake: Effect of Sex Steroid Hormones on Dendritic Spine Formation

In many seasonally breeding species, changes in the density and/or morphology of dendritic spines appears to be an active process within neural regions essential for the control of reproductive behaviors. In many cases, this neuronal plasticity has been found to be in response to changes in circulating sex steroid hormone levels. Previous studies in the red-sided garter snake found a seasonal response in dendritic spine formation as well as changes in dendritic spine density in response to circulating levels of sex steroid hormones, with dendritic spine formation greater under the influence of estrogen compared to testosterone. The current study examines the role of sex steroid hormones on the density and morphology of dendritic spines within regions shown to be critical for the regulation of reproductive behaviors in the male checkered garter snake (Thamnophis marcianus). Our study revealed that animals receiving either testosterone or estradiol exhibited greater density of dendritic spines than control animals. However, animals implanted with estrogen exhibited greater dendritic spines density compared to testosterone implanted animals. These results add to the increasing amount of evidence suggesting that estrogens, aromatized from circulating testosterone may be the active hormone setting up the pathways critical for the regulation of reproductive activity in the checkered garter snake.

P3-251 GARCIA-HERNANDEZ, JE*; CCNDOR-LUJAN, B; PADUA, A; AZEVEDO, F; ALFARO, M; KLAUTAU, M; SCHIZAS, N; University of Puerto Rico - Mayaguez, Department of Marine Science, Universidade Federal do Rio de Janeiro, Instituto de Biologia, Departamento de Zoologia, University of Puerto Rico - Mayaguez, Department of Biology; *jaaziel.garcia@upr.edu*
Diversity of calcareous sponges (subclass Calcinea) from Puerto Rico: Genetic and Morphological Evidence
An integrative molecular and morphological approach was used for the taxonomic identification of Puerto Rico's calcareous (sublcass Calcinea) sponge diversity. A total of 273 specimens of calcareous sponges were collected from 2013 through 2017 from 25 localities. Our phylogenetic results reveled a total of at least 20 different species of calcareous sponges, all belonging to the subclass Calcinea. This study is reporting a total of 13 new species of calcareous sponges, with only seven species being previously described. We report the calcareous sponge *Nicola tetela* as a new distribution record since it was previously reported only from Brazil and Curaçao. Our phylogenetic analysis demonstrated that all sponges identified as *Leucetta floridana* formed a strongly supported monophyletic group (Pp=1). Within the genus *Clathrina*, the morphologically defined species *C. aurea*, *C.* sp 1, *C.* sp. 4, *C.* sp. 5, and *C.* sp 6 are monophyletic. Our specimens from the genera *Nicola*, *Arthuria*, and *Ernstia* formed strongly supported monophyletic groups with other publicly available sequences identified as *Nicola*, *Arthuria*, and *Ernstia*, respectively. Notable exception was the genus *Borojevia*, which is depicted as a polyphyletic group.

P1-266 GARDINER, J*; BEHNSEN, J; BRASSEY, C; University of Liverpool, University of Manchester, Manchester Metropolitan University; *j.d.gardiner@liverpool.ac.uk*
Alpha shapes: Determining 3D shape complexity across morphologically diverse structures
The concept of 'shape' is something we can intuitively appreciate. However, discretising the shape of morphological features to allow comparative analysis remains difficult. Many techniques, therefore, have been developed to address this challenge. Indeed, the field of geometric morphometrics (GMM) is dedicated to analysing shape change, and provides important insights into the ecology and evolution of life. Yet not all morphological features lend themselves well to GMM techniques, particularly in the absence of clearly homologous landmarks. Here we present a new method (α-shapes) for quantifying shape complexity, using mammalian bacula as a case study. Mammalian bacula (penile bones) are an interesting example, as they possess extreme shape diversity yet contain few distinct landmarks for interspecific GMM. α-shapes involves shrink-wrapping a mesh around a set of 3D points in space (point clouds). These point clouds are representative of the study specimen, and the smaller the α, the tighter the 'shrink-wrap' around the points. In this study, microCT scans of specimens are converted into point clouds and α-shapes fitted using increasingly refined meshes (smaller α). The α that produces a mesh with a volume most closely matching the volume calculated directly from microCT are considered 'optimal'. Values of optimal α are then compared interspecifically as a means of quantifying shape complexity. The α-shapes methodology is a valuable addition to the suite of techniques available to researchers interested in morphology and shape complexity, particularly when traditional GMM analysis are deemed inappropriate.

P3-68 GARDNER, S; ASSIS, VR*; MENDONCA, MT; DE ASSIS, Vania ; Auburn Univerity, Auburn, Univ. of Sao Paulo, Sao Paulo, Auburn University; *v.regina.a@gmail.com*
RNA-Seq Provides Primers to Assess Immune Response to LPS in the Invasive Cane Toad (Rhinella marina)
Invasive species are a threat to biodiversity, and much research assessing the dispersal potential of invasive species has focused on immune responses. Immune responses can vary in energetic costs, and invaders are predicted to rely on less costly ones allowing for energy allocation to dispersal. Elevated stress from dispersal may also play a role. The cane toad (Rhinella marina) is a toxic amphibian that has been introduced to several parts of the world and is capable of rapid dispersal into new habitat. Previous studies have assessed immune parameters in these toads, but little research has evaluated responses at the gene expression level. RNA-sequencing (RNA-seq) of spleen tissue collected from cane toads 2hr post-subjection to an acute challenge of 2 µg*g body mass-1 lipopolysaccharide (LPS) revealed genes coding for multiple cytokines involved in innate immune responses such as phagocytic cell recruitment, extravasation, inflammation, and lymphocyte differentiation were significantly upregulated compared with sham-injected toads. Another group of toads were subjected to an acute stress response (via transdermal application of 15 µg of exogenous corticosterone (CORT) in peanut oil) both 1hr prior to and with LPS injection to maintain elevated CORT levels during the response, but this resulted in few differentially expressed genes compared with controls or the LPS treatment (which both received peanut oil application only). RNA-seq results were confirmed with qPCR. Although exogenous CORT did not alter the immune response to LPS 2hr post-injection, these results show the differentially expressed genes during a response to LPS, and give novel primers to assess immune investment among populations of this invasive toad.

86-1 GARNER, AM*; KLITTICH, MR; PIECHOWSKI, JM; MAKSUTA, D; BUO, C; STEFANOVIC, SR; NIEWIAROWSKI, PH; DHINOJWALA, A; Univ. of Akron; *amg149@zips.uakron.edu*
Recovery Ability of Gecko Adhesive Toe Pads After Fouling with Water or Dirt
The number of studies investigating the remarkable properties of gecko adhesive toe pads has been steadily increasing over the past few decades, particularly after the discovery that van der Waals intermolecular forces are the primary driver of gecko adhesion. The gecko adhesive system is highly multifunctional (e.g. self-cleaning, anti-wetting, reusable, etc.), in ways that synthetic versions still do not mimic. Here we briefly discuss results from two studies investigating the ability of gecko toe pads to recover adhesion after fouling with water or dirt (i.e. self-drying or self-cleaning). While the self-drying and self-cleaning ability of gecko toe pads have been demonstrated elsewhere, we investigated the effect of digital hyperextension of gecko toes on self-drying, and the influence of toe pad surface chemistry on self-cleaning. Digital hyperextension was determined to have no significant effect on the extent of self-drying, suggesting that self-drying continues to occur regardless of toe pad peeling mechanism. We also found no significant effect of toe pad surface chemistry on the rate or the extent of self-cleaning, indicating that self-cleaning is not directly dependent on toe pad chemistry. Clearly, the basis of the recovery ability of gecko toe pads will require more study in order to incorporate such capability into gecko-inspired synthetic adhesives.

P2-186 GARNER, AM; KEITH, AJ*; SCHNARRENBERGER, A; ASTLEY, HC; NIEWIAROWSKI, PH; University of Akron; *ajk148@zips.uakron.edu*

The Effects of Running Orientation on Gecko Locomotor Performance

While many studies have investigated gecko adhesive locomotion, most studies investigate gecko locomotor performance while geckos are traveling upwards on an inclined or vertical substrate. Recent studies have suggested that geckos modulate the position of their hind limbs while descending an angled substrate, and that this modulation does not appear to affect sprint velocity on substrate declines up to 45°. While there appears to be no performance decrement at relatively shallow substrate angles, it is unclear whether more challenging substrate angles would lead to different results. Given the directionality of the gecko adhesive system, traveling downward on a vertical substrate should be more difficult than traveling upward on the same vertical substrate. To test this, we studied the locomotion of eight *Gekko gecko* sprinting upward or downward on a 2-meter vertical, acrylic racetrack, oriented at both 60° or 90°. A motion capture system was used to record the position of each gecko in 3-dimensional space as a function of time. This time and position data was used to calculate: average and maximum velocity, ratio of time stopped to time moving, stride frequency, and stride length of each gecko per treatment. Here we present our preliminary data and discuss the implications for the adhesive locomotion of free-ranging geckos, as well as implementation of gecko-inspired synthetic adhesives into biomimetic robots.

S10-9 GARROWAY, CJ*; FLETCHER, QE; BALZER, E; FERRY, C; KINNUNEN, R; SCHMIDT, C; SOLMUNDSON, K; U. Manitoba, U. Winnipeg; *colin.garroway@umanitoba.ca*

Eastern Grey Squirrel Colour Morphs and Urban Adaptation

Cities are the Earth's newest major habitat and we can learn a great deal about how populations cope with environmental change by studying the species that colonise them. Eastern grey squirrels (*Sciurus carolinensis*) are strongly associated with humans and occur, at spatially varying densities, in grey, brown-black, and black colour morphs. These morphs are produced by a single deletion in a gene associated with melanin production. The melanistic allele is incompletely dominant over the wild type. Heterozygotes produce the brown-black morph. We were interested in determining whether melanistic morphs are more closely associated with urban areas than grey morphs. Some data suggests that there may be phenotypic traits, related to temperament and physiology, linked to the melanistic allele that make melanistic morphs better suited to living in urban areas than grey morphs. To test this we downloaded 6782 georeferenced photos of grey squirrels from iNaturalist.org and designated colour morphs as melanistic (black/black-brown) or not. We first used presence only species distribution modelling of environmental variables and human density to identify correlates of the distribution of all morphs pooled. Mixed wood forest cover and human density were the most important variables in the final model, each contributing ~32% to the model's explanatory power. We then fit the same model to the 896 melanistic morph samples, comparing environments where melanistic morphs occurred to those where grey morphs were sampled. Melanistic morphs were much more closely tied to the presence of humans. Human density contributed ~63% to this model's explanatory power. This suggests that there may be genetically based traits linked to the melanistic allele that contribute to urban adaptation. What these traits are remains poorly understood.

12-2 GART, SW*; MITCHEL, TW; LI, C; Johns Hopkins University; *swgart@jhu.edu*

Snakes traversing large step obstacles: behavior, gait, and performance

Forest-, river valley-, and desert-dwelling snakes often traverse complex 3-D terrain like rocks and felled trees with variable surface height and frictional properties. Despite many studies on simple flat surfaces or branches, how snakes move in such complex 3-D terrain is less known. Here, we studied how the variable king snake (*Lampropeltis mexicana*) traversed a large step obstacle (up to 25% of snout-vent length) and tested how step height and surface friction affected traversal (3 animals, 101 trials). We discovered that, to traverse, the animal first lifted its head onto the step, and then climbed by simultaneously pulling with the anterior body and pushing with the posterior body. On high friction surface, the animal climbed using a tube-following gait, and slipped little (slip angle, $\beta = 13 \pm 8°$). By contrast, on low friction surface, the animal slipped more ($\beta = 39 \pm 7°$, $P < 0.0001$, repeated-measures ANOVA), climbed using a concertina gait that alternated between pushing and pulling, and moved more intermittently. In addition, when the step was higher and/or friction was lower, the animal moved closer to the step before initiating climbing. These behavioral and kinematic differences resulted in the animal's slower traversal when step height increased and when friction decreased (e.g., traversal time $t = 30 \pm 16$ s, traversal speed $v = 1.9 \pm 0.6$ cm s^{-1} for the higher step with lower friction vs. $t = 6 \pm 1$ s, $v = 5.9 \pm 1.8$ cm s^{-1} for the lower step with higher friction, $P < 0.0001$ for time and speed, repeated-measures ANOVA). Finally, a principle component analysis showed that the animal can be approximated by superposition of planar modal shapes on flat ground that became non-planar during high step traversal. Our study demonstrated the importance of 3-D terrain geometry and mechanics in shaping locomotor behavior.

P3-184 GARTNER, SM*; MEHTA, RS; Univ. of California, Santa Cruz; *sgartner@ucsc.edu*

Organ Topology and Their Scaling Patterns in Moray Eels

Anguilliformes (true eels) are a large clade of highly elongate fishes that exhibit diverse feeding ecologies. Within Anguilliformes there is surprising diversity in the mechanisms of elongation of the body, including almost every trend for axial elongation known within actinopterygian fishes. In morays (Muraenidae), maximum body length evolves through region-specific increases in vertebral number, elongation of individual vertebral centra, and postembryonic somatic growth. In this study, we investigate postembryonic somatic growth in relation to axial patterning by investigating how organs scale over ontogeny using the California moray *(Gymnothorax mordax)* as our model. We measured the anteroposterior positions of the organs as well as their relative position to the vertebrae in morays ranging from 320-930 mm in standard length. We also measured lengths and widths of vertebral centra and the vertebral span of each organ system. We find that *G. mordax* increases its body length faster than tail length over ontogeny by increasing vertebral lengths in the precaudal region over the caudal region. We found that the majority of organ lengths scale negatively with body cavity length but many organ masses have allometric relationships with this region. Body depth scaled positively with body cavity length, which corresponds with the steep increase in mass for most of the organs. The consistent span of organ topology with vertebral number during growth suggests strong morphogen gradients during somatic growth. Our scaling trends within the California moray are interesting in comparison to studies documenting ontogenetic changes in the position of visceral organs in other elongate ectothermic predators such as snakes.

36-6 GATESY, SM*; TURNER, ML; FALKINGHAM, PL; Brown Univ., Liverpool John Moores Univ.; *stephen_gatesy@brown.edu*
CT Imaging of Dinosaur Footprints: Hidden Topography and the Origin of Track Diversity
Dinosaur footprints are trace fossils documenting the interaction of live animals with deformable substrates. Some tracks are relatively accurate molds of the foot, but most are not. Factors such as substrate consistency and foot motion are known to give rise to disparate track morphologies that may differ considerably from static pedal anatomy. Although typically viewed as surfaces, any given track is a sample of a broader, often hidden, volumetric phenomenon. Some specimens of deep tracks can be split into multiple slabs, revealing evidence of foot movement into and out of the sediment. We used CT imaging to reconstruct internal surfaces of deep tracks from the Early Jurassic (~200 MYA) of the Connecticut Valley. Our first glimpse inside these fossils reveals that natural breaks, mechanical splitting, and subsequent preparation have significantly damaged most exposed surfaces. In particular, elevated features documenting foot withdrawal were either too fragile to survive or were mistakenly removed. Such topographic structures are key to understanding how deep tracks formed and explaining the origin of footprint disparity. CT data enable us to more clearly observe the results of foot-sediment interactions than is possible from exposed surfaces alone, and serve as key constraints on reconstructions of extinct dinosaur limb kinematics.

109-4 GATICA-SOSA, C; BRZĘK, P; MAGALLANES, M.E.; KARASOV, W.H.*; CAVIEDES-VIDAL, E.; Univ. San Luis, Argentina, Univ. Biaystok, Poland, Univ. Wisconsin-Madison; *wkarasov@wisc.edu*
Intestinal α-Glucosidase Transcriptional Responses During Ontogeny and Diet Adjustment in Altricial Birds
We describe ontogenetic changes in maltasic activity and its mRNA in birds through adulthood, and in response to increase in dietary starch. We studied house sparrows (*Passer domesticus*), which undergo a natural switch from insects to starch-containing seed diet during development, and zebra finch (*Taeniopygia guttata*), which have a relatively fixed seed diet during development. In zebra finch, in whom maltasic activity increased with age but not with dietary starch, α-glucosidase mRNA was not affected by either age or dietary starch level. In house sparrow nestlings, in whom maltasic activity increased with age and with added starch, α-glucosidase mRNA was higher on diet with added starch but did not clearly increase with age. These results are consistent with the idea that the apparent programmed ontogenetic increase in maltasic activity is not mainly via transcriptional control of α-glucosidase, whereas induction of maltasic activity by increased dietary starch is.
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73-5 GAU, JF*; GRAVISH, N; SPONBERG, S; Georgia Institute of Technology, Univ. of California, San Diego; *jeffgau@gmail.com*
Elasticity and Resilience of the Hawkmoth Thorax Reduces Power Requirements
Flapping flight at the centimeter scale is one of the most energetically demanding modes of locomotion, which has led to the evolution of a resonant flight system for efficient elastic energy storage and return. In this configuration, the power muscles deform a stiff, parallel elastic exoskeleton that indirectly strains the elastic wing hinge to drive the wing. The wing hinge has been implicated in energy storage due to the presence of resilin - the most elastically efficient biological protein yet discovered. Cross-bridges have also been identified as potential storage sources. Because these materials have relatively low stiffness and displacement amplitudes (0.46 mm in downstroke power muscles), it is possible that other structures play significant roles in energy storage as well. Therefore, to understand the energetic consequences of this actuation method, we characterized the dynamic material properties of the thoracic exoskeleton in the hawkmoth *Manduca sexta*. We isolated the exoskeleton and drove sinusoidal length sweeps from 0.1 to 90 Hz with physiological amplitudes. To fully deform the thorax requires 1.2 N, which is 50% of the power muscles' maximum force output. This corresponds to approximately 100% of *in vivo* force generation. The thorax was 70% elastically efficient across a wide range of frequencies and amplitudes. This lead to a total body-mass specific power return of 5 W kg^{-1}, which reduces inertial power demands by 20%. In conclusion, inertial power can be reduced by an additional 80% and this value may be constrained by the *in vivo* muscular force output. This work lays the foundation for developing a mechanical representation of the flight apparatus for better quantification of indirectly actuated, resonant flight energetics.

P1-193 GAVIRA, RSB; ANDRADE, DV*; Depto de Zoologia, IB, UNESP. Rio Claro, SP, Brazil; *denis@rc.unesp.br*
Resting Metabolic Rate and Evaporative Water Loss in Neotropical Pitvipers. Are There a Relationship with Microhabitat Use?
Ectothermic animals rely primarily on external heat sources and behavioral adjustments for body temperature (Tb) regulation. As the availability of adequate thermal niches varies spatially and temporally, these organisms are subjected to considerable fluctuations in Tb. In its turn, fluctuations in Tb exert profound influence on physiological and behavioral performances. For example, resting metabolic rate (RMR) and evaporative water loss (EWL) are typically related to Tb. Also, RMR and EWL are known to vary interespecifically and with habitat characteristics. Herein, we addressed the ecophysiological potential implications of the variation in metabolism and water balance in a group of Neotropical Crotalinae snakes. To this aim, we measured oxygen consumption rates (as a proxy for RMR) and EWL rates at different temperatures (15, 25, and 35°C) for the following snake species: *Bothrops alternatus*, *B. jararaca*, *B. moojeni*, and *Crotalus durissus*. These snakes are phylogenetic related and occupy geographical areas that overlap extensively, however, they differ in microhabitat use and other life history attributes. In general, *B. jararaca* and *B. moojeni* occupy forested areas, whereas *B. alternatus* and *C. durissus* are open area dwellers. We found that RMR and EWL increased with temperature in all snake species. *Bothrops jararaca* and *B. moojeni* had higher RMR than *B. alternatus* and *C. durissus* at 15 and 35ºC. EWL of *C. durissus* was the lowest among all the species tested, regardless temperature. At 35°C, *B. alternatus* had lower EWL than other *Bothrops*. Broadly, differences in RMR and EWL seem to be consistent with differences in microhabitat occupancy. Financial support: São Paulo Research Foundation (FAPESP)

P2-271 GüELL, BA*; WARKENTIN, KM; Boston University; *bguell@bu.edu*

Does accelerated development impair predator-detection and escape-hatching of phyllomedusid treefrog embryos?

Many embryos hatch at different developmental stages in response to environmental conditions, using cues in multiple sensory modalities. This is widespread and particularly well studied in amphibians. Phyllomedusid treefrog embryos hatch prematurely in response to hypoxia when flooded and physical disturbance by predators. Recent work on *Agalychnis callidryas* suggests that hypoxia-cued hatching begins when hatching ability develops, but mechanosensory-cued hatching begins slightly later, once inner ear mechanoreceptors develop. Effective escape-hatching responses to flooding appear ancestral and conserved in phyllomedusids, but responses to snake attacks vary among species. Specifically, the faster-developing species *A. spurrelli* and *A. saltator* have lower escape success in snake attacks. We hypothesized that this variation in escape-hatching success might be due to differences in the relative timing of key developmental events. If accelerating development affects hatching mechanisms more than ears, it could increase periods when hatching-competent embryos cannot perceive mechanosensory cues. To test if changing development rate differentially affects the onset of escape-hatching responses to different cues, we reared *A. callidryas* embryos at cool, ambient, and warm temperatures. Warmed embryos developed faster while cool ones developed much slower. We then assessed the onset of hatching responses to hypoxia and mechanosensory cues. Across thermal treatments, embryos began responding to each cue type at a consistent developmental stage, although the absolute timing of response onset differed. This suggests that developing faster need not always entail a lag in predator-detection ability. Why hatching-competent, but premature, embryos of some *Agalychnis* species fail to flee from predators remains enigmatic.

128-2 GE, Z*; TOOMEY, M; HILL, GE; Auburn University, Washington University, Saint Louis; *zzg0008@auburn.edu*

Red ketocarotenoids found inside mitochondria in Haemorhous mexicanus

For decades, carotenoids-based coloration has been one of the most extensively studied ornamentations in birds, they are responsible for many of those yellow, orange and red colors in birds' feather, beak, and skin. Carotenoid-based coloration, especially red coloration, is also an important criterion for mate choice in many different taxa including birds, and it's one of the most classic examples of honest signals in sexual selection. Unlike yellow carotenoids, which can often be obtained directly from the diet, red ketocarotenoids are usually not readily available in songbirds' diet and must be generated through metabolic conversion of those yellow dietary carotenoids. Despite the wide interest and tremendous effort on understanding the function of these red pigments, the site of carotenoid metabolism remains uncertain and contentious. In previous work, we've located a high concentration of ketocarotenoids in hepatic mitochondria extraction from house finch (*Haemorhous mexicanus*), indicating a potential link between mitochondria and ketocarotenoid conversion. In this study, we successfully separated matrix and inner mitochondrial membrane from the outer mitochondrial membrane. And by running carotenoid analysis on each of those fragmentations, we found a high concentration of red ketocarotenoids to be inside mitochondria, and most likely on the inner mitochondrial membrane. This work has an important implication for the cellular mechanisms that regulate the production of ornamental plumage coloration as well as the shared pathway hypothesis, which suggests the production of carotenoid pigmentation is intimately linked to core cellular processes like cellular respiration in mitochondria.And this is the very first study reporting submitochondrial location of red ketocarotenoids in animals.

P2-164 GEARHART, C; PINSHOW, B*; KORINE, C; Ben-Gurion University of the Negev; *pinshow@bgu.ac.il*

Variation in Evaporative Water Loss among Kuhl's Pipistrelles along an Extreme Climate Gradient in Israel

There is evidence that some desert-dwelling bats have lower rates of evaporative water loss (EWL) than non-desert species, but whether there are differences in EWL among populations of conspecifics over a range that includes both mesic and desert habitats is unknown. One such species is *Pipistrellus kuhlii* , which originated in Mediterranean climes, but is now found also in hyperarid habitats in southern Israel. We hypothesized that populations of *P. kuhlii* from habitats with different climates have phenotypic differences that reflect the climatic conditions of their habitat and we tested the prediction that EWL, especially at high ambient temperatures (T_a), is lower in bats from desert habitats. We measured EWL in three populations of *P. kuhlii* at four T_as and found a significant effect of group origin on EWL. Mean total EWL in the group from the hottest (most southerly) region was significantly lower than in the intermediate and Mediterranean groups at T_a = 35 ºC. Reduced EWL in desert populations of *P. kuhlii* likely saves water and may reflect phenotypic plasticity or genetic adaptation, a question that we intend to explore in the future.

P1-104 GEARTY, W*; PAYNE, JL; Stanford University; *wgearty@stanford.edu*

Convergent body size evolution of Crocodyliformes upon entering the aquatic realm

Twenty-four species of crocodile populate the globe today, but this richness represents a minute fraction of the diversity and disparity of Crocodyliformes since their origin early in the Triassic. Across this clade, three major diversification events into the aquatic realm occurred. Aquatic and terrestrial habitats impose differing selective pressures on body size. However, previous research on this topic in Crocodyliformes remains qualitative in nature. In this study, our goal was to quantify the influence of habitat (terrestrial versus aquatic) on the evolution of body size in Crocodyliformes. By compiling an extensive body size database of fossil and modern crocs and using phylogenetic comparative methods, we find a history of repeated body size increase and convergence coupled with increases in strength of selection and decreases in variance following shifts to an aquatic lifestyle, suggesting common selective pressures on life in water spanning multiple independent aquatic clades. Lung volume, which has long been proposed as the main constraint on diving time, is only a constraint at sizes greater than 10 kg, whereas the rate of cooling constrains diving time at sizes less than 10 kg. Therefore, we propose this may be the primary driver of larger body sizes in aquatic crocodyliformes.

37-1 GEFEN, E*; TALAL, S; AYALI, A; Univ. of Haifa- Oranim, Israel, Tel Aviv University, Israel; *gefene@research.haifa.ac.il*
On the Mechanistic Basis for Discontinuous Gas Exchange in Actively Ventilating Insects
Several adaptive and non-adaptive hypotheses for the evolution and expression of discontinuous gas exchange (DGE) in insects have been proposed. Our recent work on orthopterans joins a large body of evidence, which questions the generality of the available hypotheses. Results from interspecific and intraspecific comparisons and an experimental evolution study are not consistent with predictions of adaptive and non-adaptive explanations. Still, they provide insights into the mechanistic basis of DGE in actively ventilating insects. Simultaneous electromyogram and respirometry reveal two distinct forms of ventilation in intricate interplay with three possible spiracular states. During the burst of gas exchange, alternating closure of abdominal and thoracic spiracles is coupled with activity of abdominal ventilatory muscles to achieve fast unidirectional ventilation through major tracheal trunks. Ventilation frequency during this phase gradually decreases in response to changing tracheal gas composition. During the interburst, when there is negligible gas exchange with the environment, locusts ventilate their tracheal content in order to facilitate diffusion through the fine tracheoles. This is achieved through slow ventilation activity, coupled with increased activity of spiracular closer muscles, and is triggered by decreasing tissue O_2 levels. A classic "flutter phase", characterized by short bursts of CO_2 emission, is missing in locusts in normoxia, but is evident under hypoxic conditions. These short events of CO_2 release result from fast ventilation events and transient relaxation of spiracle closure muscles. A model consisting of two separate pattern generators with converging output could explain the observed motor activity throughout the DGE cycles.

P1-186 GEIGER, C/M*; SCHWEIZER, K/G; PILLOT, A; MEADOWS, M/G; Saint Francis University; *cxg154@francis.edu*
The Effects Moon Jellyfish Have on the Biodegradation of Oil Spills.
Oil dispersion begins immediately following a spill and is detrimental to ocean ecosystems. However, this dispersal process facilitates bioremediation and eventually leads to mitigation of the spill, enabling ecosystems to recover. *Aurelia aurita*, also known as moon jellies, have mucus which houses hydrocarbon-consuming bacteria that have been shown in previous research to consume crude oil. Additionally, the jelly mucus aggregates oil droplets from the water column. In our study, we are testing the hypothesis that a greater number of live jellies results in faster and more complete crude oil consumption via the nitrogen and phosphorous nutrients in their mucus, which supports bacterial growth. For this study, we constructed 3 custom aquaria that are built with circular water flow. Our treatments include 3 equally-sized 12-gallon aquaria housing one jelly, two jellies, and a no-jelly control, each with the same amount of crude oil added every week for 10 weeks. Every week following 6 days under treatment, we quantify nitrogen and phosphorous in all treatments as well as the number of oil droplets in mucus released by the jellies in the jelly treatments. We predict that aquaria with more jellies will have higher levels of nitrogen and phosphorous, which would support more bacterial growth, and more droplets of oil trapped in jelly mucus. Our results will be discussed.

P2-193 GELLMAN, ED*; BURKE, T; NTIM-ADDAE, N; NWAKO, J; ELLERBY, DJ; Wellesley College; *egellman@wellesley.edu*
Intermittent propulsion during volitional swimming in bluegill sunfish
Most fish swimming performance data were obtained under steady-state conditions at imposed constant velocities. In contrast, field videography suggests that volitional swimming features velocity variation and non-linear trajectories. A further distinction in bluegill sunfish (*Lepomis macrochirus*) is that flume swimming involves repeated propulsive cycles, while volitional swimming features intermittent propulsive bouts interspersed with gliding. If drag is elevated during thrust production, brief bouts of thrust interspersed with low-drag, low-cost gliding could reduce overall energy costs relative to constant propulsion at the same average speed. Intermittent propulsion may also keep muscle strain trajectories and propulsive kinematics within a narrow parameter space that maximizes muscle power output and/or muscle and propulsive efficiencies. If so, speed modulation may be achieved by changing propulsive and glide durations rather than propulsive cycle frequency as in constant-propulsion flume swimming. Detailed kinematic data are required to determine the factors underlying intermittent propulsion. Resolution limits make this information difficult to obtain in the field. To address this, we have quantified volitional swimming performance data in a large-volume tank that allows for unconstrained swimming. Propulsive cycle frequencies, estimated muscle strains and Strouhal numbers fell within a narrow range, and were largely decoupled from average speed. This suggests that constraints on propulsive muscle function and kinematics may underlie intermittent propulsion. The similarities between volitional velocities and propulsive cycle frequencies between the lab and field suggest that this approach can be applied to understand selection pressures shaping intermittent propulsive behavior.

P1-188 GENTILE, G*; DWAAH, H; CAMILLI, S; HALL, C; RIESGO, A; SORIONO, O; HILL, M; HILL, A; HILL, April; Univ. of Richmond, Virginia, Univ. of Virginia, Natural History Museum, London; *ahill2@richmond.edu*
Development of a Model System to Study Sponge:Algal Symbioses
In many freshwater habitats, *Chlorella* spp. form intracellular symbioses with a variety of heterotrophic host taxa including several species of freshwater sponge. The facultative nature of the sponge:*Chlorella* association offers opportunities to identify factors that permit long-term residency within organelles, and to discern pathways that allow the algae to avoid the host's digestive response. Freshwater sponges also offer many tractable qualities of a model system to study features of intracellular occupancy. Here, we describe how we isolated, cultured, and cared for sponge-derived *Chlorella*, and how we obtained, curated, and grew *Ephydatia* gemmules. We also describe how we used the emergent sponges in experiments to test hypotheses about *Chlorella* symbioses. The fate of *Chlorella* populations was followed after inoculating algae-free *E. mülleri* and *E. fluviatilis* under different experimental conditions. Furthermore, we present RNASeq data on differential gene expression observed in *E. mülleri* exposed to bacteria, heat-killed *Chlorella*, and live *Chlorella*. We discuss this work in light of growing interest in the evolution of specificity between hosts and symbionts, the stability of algal populations in heterotrophic hosts, and the fundamental and realized niche of phototrohpic algae.

9-3 GENZ, J*; GILBERT, C; SVENDSEN, JC; University of West Georgia, Technical University of Denmark; *jgenz@westga.edu*

Combined Effects of Temperature and Hypoxia on Anaerobic Metabolism and Development of Oxygen Debt in a Common Cyprinid

The golden shiner, *Notimigonus crysoleucas*, is a common bait minnow that often experiences hypoxia events within its freshwater habitat, and also encounters many microhabitats of varying temperatures. In this experiment, golden shiners were exposed to severe hypoxia (1.75±0.12 kPa) for 1 h at two environmentally-relevant temperatures (14 and 24°C), and then allowed to recover for 7 h at 24°C. Standard and maximal metabolic rates and blood plasma parameters were assessed before hypoxic exposure, immediately following exposure, and post-recovery. We hypothesized that cold temperature in combination with severe hypoxia may create a protective effect with respect to the metabolic response. Standard metabolic rate was significantly decreased during hypoxia in the fish exposed to 14°C, but was not affected at 24°C. Golden shiners exposed to hypoxia at 24°C accumulated a greater oxygen debt than the 14°C treatment, but time required to return to pre-exposure SMR was not significantly affected by exposure temperature. Blood plasma lactate concentrations were significantly elevated in golden shiners immediately following hypoxia at both temperatures, and returned to baseline levels after the 7 h recovery period in both groups. Fish exposed to hypoxia in low temperature displayed significantly lower plasma lactate accumulation immediately following hypoxia exposure than fish exposed at 24°C. Similarly, plasma pH was reduced following hypoxia exposure, but only in the fish held at 24°C during hypoxia exposure. These results indicate that, consistent with other cyprinids, golden shiners demonstrate extensive hypoxia tolerance, which is enhanced by reduced temperature.

19-4 GEORGE, EM*; NAVARRO, D; ROSVALL, KA; Indiana University, Bloomington, Texas A&M University-Kingsville; *georgee@indiana.edu*

Short-term HPG axis activation has longer-term effects on paternal care: implications for the use of GnRH challenges

Gonadal steroids, such as testosterone (T), mediate many reproductive and social behaviors in vertebrates. It is therefore useful to experimentally manipulate T levels in order to investigate how these hormone-mediated traits may be shaped by selection. One commonly used method to temporarily increase T within physiological ranges is to stimulate the hypothalamo-pituitary-gonadal (HPG) axis with injections of gonadotropin-releasing hormone (GnRH). However, despite their frequent use as an assay of HPG axis reactivity, the effects of GnRH injections on behavior are poorly understood. Here, we tested the effects of GnRH vs. saline injections on parental care in free-living male tree swallows (*Tachycineta bicolor*) during the chick rearing period. To measure effects on paternal care in the 24 h post-injection, we quantified RFID-logged nest visitation rate (i.e. provisioning) and nestling growth. Because prior work suggests that T often suppresses paternal care in songbirds, we expected to find temporarily reduced care in GnRH males vs. saline males. Surprisingly, we found the opposite: GnRH-injected males visited their nest boxes significantly more than controls, and their chicks tended to grow faster. Additionally, the degree to which males elevated T in response to GnRH positively correlated with the rate at which their chicks grew. Together, these data suggest that males experiencing a surge in T, or some other GnRH-controlled hormone, provision more than controls. Results also highlight the utility of GnRH challenges, which can temporarily elevate gonadal steroids within physiological limits and, in doing so, reveal behavioral and performance-related consequences of naturalistic hormonal fluctuations.

74-1 GEORGE, MN*; CARRINGTON, E; Univ. of Washington, Seattle; *mngeorge@uw.edu*

Mussel Byssus Attachment in a Patchy Ocean: pH and Dissolved Oxygen at the Substrate-Adhesive Interface Diverges from Oceanic Conditions in Mussel Aggregations

In the intertidal zone, where waves impart lift and drag forces on stationary objects, mussels survive by forming aggregations, where individuals adhere to rocks and each other using fibers (byssal threads) tipped with a protein-based adhesive. Single protein adhesion models predict that a pH and oxygen differential imposed during secretion promotes adhesion with the substrate, while exposure to seawater facilitates the solidification and cross-linking of proteins to form a bulk solid. What remains unclear is to what extent pH and oxygen at the substrate, and in aggregations, differs from open ocean conditions, and to what extent this difference impacts adhesive strengthening. Here we present substrate level pH and oxygen measurements from mussel aggregations that are suspended during raft aquaculture operations at the Penn Cove Shellfish Farm, in the Puget Sound, Washington State. Field observations of pH and oxygen were used to inform fluctuating laboratory experiments, wherein byssus adhesive was incubated in seawater treatments, sampled over time, and pulled to failure using a tensile testing machine. Excursions below a pH of 7 were sufficient to arrest adhesive strengthening, which then resumed when seawater returned to a pH of 8. Oxygen fluctuations below 1 mg L^{-1} failed to stop adhesive strengthening over a three-day exposure, although the rate of strengthening was reduced. Results from these assays provide insights into what substrate-level micro-environment is required for secure mussel attachment, answers whether or not this interaction is reversible or temporally constrained, and can be used to inform a dynamic model that predicts the timing of "fall off" events at mussel farms given changes in future oceanic conditions.

P1-216 GERALD, GW*; WASS, ED; NOVINSKI, D; PROKUPEK-PICKETT, A; MARIAN, AD; MCGINN, TM; Nebraska Wesleyan University, College of Charleston; *ggerald@nebrwesleyan.edu*

Differential gene expression and citrate synthase activity in skeletal muscle of cornsnakes (Pantherophis guttatus) following different modes of locomotion

Variation in locomotor performance and metabolism is common in animals; however, the underlying causes driving this variation have received little attention. Though, previous studies have shown changes in enzyme activity and metabolic gene expression in exercised versus non-exercised skeletal muscle, no study has examined the plasticity in enzyme activity and gene expression in skeletal muscle following different types of locomotor activity in non-human animals. Snakes are excellent candidates to use to examine these questions because of the various types of locomotor modes they utilize and because they possess metabolic proteins unique among vertebrates that are involved in aerobic respiration and which permit them to endure large metabolic fluctuations. For this study, biopsies of skeletal muscle were performed on cornsnakes (*Pantherophis guttatus*) following 10 min of movement via one of three modes of limbless locomotion (lateral undulation, concertina, arboreal) to 1) extract RNA for sequencing and quantify gene expression and 2) to examine citrate synthase activity. Sequences were assembled using de-novo and genome-guided methods and a consensus assembly was used to annotate and assess differential gene expression. More genes were found to be up- or down-regulated following lateral undulatory and concertina movements compared to arboreal movement. We found that citrate synthase activities did not differ among locomotor treatments but was higher than snakes that did not move. Future work will attempt to identify the functions of up- and down-regulated genes and examine the activities of other metabolic enzymes.

109-3 GERMAN, DP*; HERRERA, MJ; HERAS, J; Univ. of California, Irvine; *dgerman@uci.edu*

Can you stomach it? Comparative transcriptomics of the stomachs of prickleback fishes (Stichaeidae) consuming different diets

Despite obvious whole animal, tissue level, and biochemical differences among species with different diets, dietary specialization has molecular underpinnings that are not well understood. In this project, we used comparative transcriptomics of stomach tissues to observe how prickleback fishes (Stichaeidae) achieve dietary-driven differences in stomach function. *Xiphister mucosus* (herbivore), *X. atropurpureus* (omnivore), *Phytichthys chirus* (omnivore) and the carnivorous *Anoplarchus purpurescens* were harvested from the wild, and fed omnivore and/or carnivore diets in the laboratory. Using the Illumina platform, transcriptomes were sequenced for stomach tissues from two individuals per species and diet treatment, and genome-driven assemblies were performed using the *Cebidichthys violaceus* genome as the reference. Analyses are underway, but we will present data on differential expression, and enrichment of genes involved in acid production, as well as digestion of protein and chitin. We have previously observed differences in gastric pepsin and chitinase activities in these species, and will reveal whether these activity differences are the result of changes in gene expression. This broader transcriptomic analysis will allow us to extend our coverage beyond a single digestive enzyme gene to the multitude of genes involved in the stomach, and will provide insight into how the vertebrate stomach can specialize to use specific resources.

82-4 GERRINGER, ME*; ANDREWS, AH; HUSS, GR; NAGASHIMA, K; POPP, BN; GALLO, ND; CLARK, MR; LINLEY, TD; JAMIESON, AJ; DRAZEN, JC; University of Hawai'i at Mānoa, Honolulu, NOAA Fisheries, Pacific Islands Fisheries Science Center, Honolulu, Scripps Institution of Oceanography, University of California San Diego, La Jolla, National Institute of Water and Atmospheric Research, Wellington, New Zealand, Newcastle University, Newcastle Upon Tyne, United Kingdom; *mackenzie.e.gerringer@gmail.com*

Life history of abyssal and hadal fishes from otolith analyses

Several hadal trenches, depths (6,500-11,000 m), house groups of apparently endemic snailfishes (Liparidae). Little is known about their biology, nor the reasons for their success at hadal depths around the world. We investigated the life history of hadal liparids in comparison to abyssal species (Macrouridae) through otolith analyses. Assuming opaque zones in the otoliths represent annual growth, ages were estimated for the two hadal species to be between 5 and 16 years old. Age estimates for abyssal macrourids ranged from 8 to 29 years for *Coryphaenoides armatus* and 6 to 16 years old for *C. yaquinae*. In addition, $^{18}O/^{16}O$ isotopic compositions ($\delta^{18}O$) were measured across the otolith using an ion microprobe to investigate the thermal history of these fishes. Changes in $\delta^{18}O$ were observed across the otoliths of *C. armatus* and both hadal liparids, the latter of which may represent a change of over 5°C in habitat temperature through ontogeny. This result was unexpected for the hadal liparids given their isolated environment and large eggs. The biological implications and plausibility of interpretations of these data are discussed. This study presents a first look at the life history of the planet's deepest-living fishes.

P1-4 GIBB, A.C.; Northern Arizona University; *alice.gibb@nau.edu*

Teaching Using "The Martian:" A Problem-solving Based Approach to Physiology

The challenge of maintaining human life in a non-earth environment illuminates the fundamental physiological problem of homeostasis. The astronaut depicted in "The Martian," first a novel by Andy Weir and then a blockbuster movie directed by Ridley Scott, is stranded alone on Mars and must rely NASA's technology and his own ingenuity to stay alive. Using scenarios outlined in the novel, students are asked to consider the metabolic demands of the human body for oxygen, water, and energy, as well as the physiological requirements associated with maintaining a constant body temperature. Within this context, we ask and answer the following questions: (1) why do humans inhale oxygen and exhale carbon dioxide and in what biochemical pathways do these gases serve as reactants/products? (2) how are blood gases regulated and what the the consequences of disequilibrium conditions? (3) what determines a human's energy requirements and what types of foods contain the most calories? and (4) why do human bodies only function at certain temperatures and how is body temperature regulated? By combining readings from the novel and YouTube clips from the movie with secondary and primary literature sources (including NASA publications), students are asked to "think outside of the box" and contemplate the problems that arise when sea-level earth constants (atmospheric pressure, percent oxygen composition, etc.) are no longer in effect. Students in the class learn to quantify and solve physiological problems, integrate core concepts across organ systems, and gain a working knowledge of the primary feedback mechanisms that maintain a constant internal environment --- with an overarching goal of improving students' understanding of how humans survive on earth and, with the assistance of technology, in much more hostile environments.

P2-85 GIBBS, AG*; BENITO, S; NEVAQUAYA, V; Univ. of Nevada, Las Vegas, University of Science and Arts of Oklahoma; *allen.gibbs@unlv.edu*

Starvation recovery in starvation-selected Drosophila

Long-term selection for starvation resistance in *Drosophila melanogaster* has resulted in populations that accumulate high lipid levels during an extended larval developmental period. These lipids are used to survive 14 days without food each generation. Flies that do survive must then re-accumulate resources for reproduction. We measured lipid content in starvation-selected (S) and fed control (F) flies subjected to severe starvation stress (10 days for S flies, 3 days for F flies). We also performed a larval starvation experiment. When F larvae stopped feeding and began wandering for a pupation site, S larvae were removed from their media to prevent them from acquiring additional lipids. In both cases, S and F flies regained their lipid content over a period of several days. Our data suggest that S flies have evolved a higher lipid storage set point than controls, and this set point is not affected by changes in caloric intake as larvae or as adults. Supported by the AANAPISI Scholars Institute at UNLV and NSF awards IOS-1355210 and DBI REU 1358896.

P2-86 GIBBS, AG*; PARMAR, N; PATEL, P; HARDY, CM; UNLV; *allen.gibbs@unlv.edu*

Divergent responses to experimental selection for starvation resistance

Experimental evolution uses replicated, populations that generally evolve along similar trajectories, but can diverge over time. We selected for starvation resistance in 3 populations (S) of *Drosophila melanogaster*. After ~100 generations of selection, S populations survived >11 days without food, whereas fed control (F) flies survived less than 4 days. One S replicate consistently survived >24 hours longer than the other populations, and genomic data revealed significant divergence in SNP allele frequencies across the genome. To identify the mechanisms underlying these differences, we analyzed energy budgets of S and F flies. Starvation survival can be increased by three non-exclusive physiological mechanisms. S flies can store more energy before selection is imposed, they can use energy less rapidly, or they can tolerate lower energy contents (i.e. utilize a greater proportion of initial energy stores before dying). Flies may also ingest microbes that have colonized corpses of flies who have already died ("cannibalism"), or acquire energy from fecal material (coprophagy). S flies stored 3-4 times more lipid than controls. Their metabolic rates were ~25% lower, but they did not consume a greater fraction of initial lipid before death. Both S and F flies survived longer in vials containing fly corpses, but selected flies were not "better" cannibals. The presence of large quantities of fecal material did not affect survival. In all assays, replicate populations did not differ significantly. We conclude that population divergence in starvation survival is likely the result of relatively small changes in lipid storage and metabolic rate that were statistically undetectable, but together have a significant effect on starvation resistance. Supported by IOS-1355210 from NSF and R15-GM100395 from NIGMS.

P1-292 GIBSON, JG*; ANDERSON, PS; University of Illinois at Urbana-Champaign; *jcgibso2@illinois.edu*

Kinematics and Functional Morphology of Mantisfly (Neuroptera: Mantispidae) Raptorial Strikes

Raptorial appendages have evolved multiple times in arthropods, lending these groups to studies on comparative biomechanics and evolution of raptorial strikes. While the strike kinematics of mantises and mantis shrimp are well studied, comparatively little is known about the strikes of other raptorial arthropod groups, including mantisflies (Family Mantispidae). Here, we use high speed videography to characterize strike kinematics of two mantisfly species: *Climaciella brunnea* (Say) and *Dicromantispa sayi* (Banks), and compare these results to published data on the strikes of mantises and mantis shrimp. We found that *C. brunnea* and *D. sayi* have strikes comparable to mantises, with the femur (the primary lever arm in both groups) reaching maximum rotational velocities similar to mantises (2500-5600 deg/s). The speeds of these strikes suggest that, unlike mantis shrimp, mantisflies are not using a spring and latch system to increase the power output of their strikes. The biggest difference between mantises and mantisflies is in the starting angle of the coxa-femur joint. In mantisflies, the femur starts at an initial angle of -30 degrees prior to the initiation of the strike and moves through an arc of 120-200 degrees, compared to an initial femoral angle of 5-10 degrees and an arc of around 70 degrees in mantises. This likely gives mantisflies more time to accelerate their femurs to a higher peak velocity, and may help to compensate for their smaller femur extensor muscles housed within their thin coxae. This study is the first to characterize the kinematics of mantisfly strikes. Future work will attempt to characterize the strike kinematics of other raptorial limbed arthropods, with the goal of conducting a large scale comparative study across groups.

61-5 GIBSON, JC*; BOOHER, DB; ECONOMO, EP; SUAREZ, AV; University of Illinois at Urbana-Champaign, University of California Los Angeles, Okinawa Institute of Science and Technology; *jcgibso2@illinois.edu*

Kinematics, Evolution and Functional Morphology of Miniature Trap-Jaw Ant (Strumigenys spp.) Mandible Strikes

Power amplifying "trap-jaws" have evolved independently multiple times in ants, making them ideal for research on comparative biomechanics and on the relationship between form and function. However, most research on trap-jaw ants has focused on a single group and the remaining independent origins of trap-jaws have not been studied in detail. We used high speed videography and micro CT to describe the strike kinematics and functional morphology of miniature trap-jaw ants (*Strumigenys* spp.). We examined 15 species of *Strumigenys* chosen to represent morphological and phylogenetic diversity. We found a large amount of variation in morphology and performance among species in properties such as body size, mandible length and shape, bite gape, rotational velocity, and power output. Like other trap-jaw ants, *Strumigenys* have some of the fastest predatory movements known in the animal kingdom, with strikes of some species occurring in less than 0.006 ms and reaching maximum linear velocities greater than 60 m/s. Based on power output, we determined that not all species of *Strumigenys* possess power amplifying mandibles, and that power amplification has independently evolved at least 3 times within this genus. Strike performance scales with body size in a similar manner to scaling relationships seen in other trap-jaw groups. Results from micro CT scans show a high degree of morphological convergence between muscle arrangements in groups that have evolved power amplification mechanisms. Future work will focus on large scale comparisons between *Strumigenys* and other independent origins of power amplification mechanisms in ants.

P1-5 GIDMARK, NJ*; FARINA, S; Knox College, Harvard University; *gidmark@knox.edu*

A laboratory exercise for Physiology and Comparative Anatomy teaching that leverages the power of 3D printing.

3D printing offers a novel avenue for hands-on science and classroom laboratory exercises because it allows students to actually feel 3D anatomy and physically measure attributes of models. Classical studies using authentic skeletal material are phenomenal, but it can be difficult to exclusively demonstrate a single physical attribute (e.g. jaw-closing out-lever) without confounding anatomical change. We have designed a laboratory exercise where students physically measure (using calipers) mechanical parameters of 3D-printed skulls (e.g. lever mechanics of the jaw) and anatomical determinants of muscle force (muscle belly volume) to calculate biting force in two distinct 3D printed models: a dog and a primate. Then, alternative models of muscle architecture are used whereby muscle fiber length either: 1) spans the entirety of MTU length; or 2) is the shortest possible length to create a contracting moment (i.e. is almost perpendicular to the MTU line of action). The third step in the exercise involves a digitally altered primate skull, whereby the out-lever (i.e. the rostrum and anterior teeth) has been digitally elongated to give the same mechanical advantage (in-lever to out-lever ratio) as the dog, but without altering the input muscle force, mechanical advantage, or adductor muscle volume. This exercise effectively leverages (pun completely intended) the utility of 3D printing to underscore specific anatomical characteristics (e.g. jaw output lever change) without confounding factors (e.g. cranial elongation).

P2-32 GIFFORD, ME*; ROBINSON, CD; University of Central Arkansas; *megifford@uca.edu*
Effects of exogenous T3 exposure on embryonic and hatchling phenotypes in an oviparous lizard
It is well known that maternal effects can be a powerful mechanism generating phenotypic variation with potentially important consequences for fitness. Prenatal maternal effects, often mediated by embryonic exposure to maternal hormones, have been identified as a particularly important form. So far, most studies concerning maternally transferred hormones have focused on steroid hormones (e.g., corticosterone and testosterone). Eggs from several oviparous species have also been documented to contain thyroid hormones (TH). THs are known to play important roles in the development of various organ systems and in metabolism. Therefore, if THs are transferred to developing embryos, they could represent another hormonal mechanism through which hatchling/juvenile phenotypes can be influenced with potential fitness consequences. In this study we examined the effects of elevated yolk T3 concentration on several embryonic and hatchling lizard traits, including incubation time, morphology, and metabolic rate. After measurements, hatchlings were also released into the field to attempt to assess variation in hatchling survival.

87-8 GIGNAC, PM*; KLEY, NJ; Oklahoma State University Center for Health Sciences, Stony Brook University; *paul.gignac@okstate.edu*
High-resolution diceCT imaging for comparative neuroanatomical studies
Advancements in imaging techniques have drastically improved our ability to visualize, study, and share complex, often minute, anatomical relationships. The recent adoption of soft-tissue X-ray imaging tools, such as diffusible iodine-based contrast-enhanced computed tomography (diceCT), is beginning to offer previously unattainable insights into the configurations of soft-tissue complexes across Metazoa. As a contrast agent, dissolved iodine diffuses deeply to bind fats and carbohydrates that are naturally present throughout metazoan soft tissues, predictably altering tissue densities. Like the current gold standard, magnetic resonance imaging (MRI), diceCT does not require physical dissection and can differentiate between the lipid content of myelinated versus non-myelinated tissues, offering great potential for neuroanatomical studies. This is especially true for small specimens (e.g., embryos and neonates of nearly all taxa, adults of diminutive forms), which require resolutions of < 25 µm to image clearly—well below the typical 100-250 µm scales of MRI. Within the brain, diceCT distinguishes myelinated fiber tracts from unmyelinated cortices, nuclei, and ganglia, and allows 3-D visualization of their anatomical interrelationships at previously unrealized resolutions. In this study we illustrate the utility of diceCT for the rapid visualization of both external and internal brain anatomy in vertebrates—alongside cranial osteology, complete peripheral nerve pathways, and targets of innervation. We demonstrate its transformative potential for developing high-resolution, neuroanatomical datasets and describe best practices for imaging large numbers of specimens for evolutionary study and broad data sharing.

11-3 GILBERT, AL*; MILES, DB; Ohio University; *anthony.gilbert09@gmail.com*
The constraints, costs, and limits of phenotypic plasticity in response to climate warming: predicting phenotypes given idiosyncrasy in environmental change
The role of phenotypic plasticity in mediating responses to climate warming remains a heavily-debated topic in global change biology. However, "plasticity" is used across multiple contexts and often without specification of the cue which elicits the plastic response. The environmental effects of climate warming are not likely to be uniform nor predictable, and distinct environmental cues should alter the shape and form of phenotypic plasticity such that a single estimate of plasticity cannot capture the likely range of phenotypes produced by climate change. Here, we create a framework to estimate the direction of phenotypic change given multiple environmental changes of climate warming for the ornate tree lizard. We varied the environmental cue of phenotypic plasticity such that individuals were exposed to (1) a limited availability of energetic resources, (2) short-term and severe thermal fluctuations, and (3) a long-term and thermally variable acclamatory regime and assessed how these cues influence key behavioral and physiological traits. Plasticity in response to energetic resource limitation results in phenotypic shifts in thermal performance curves and thermal preference favoring cooler temperatures. Exposure to sub-lethal temperatures acutely increases thermal tolerance, but results in a trade-off with both performance capacity and thermoregulatory effectiveness. Local adaptation alters the expression of plasticity, however as acclimation temperature increases, thermoregulatory behavior and thermal physiology shift to exploit cooler temperatures. There exist multiple constraints on using limited estimates of plasticity for forecasting species responses to climate warming, and our work demonstrates a holistic design that can quantify the directions of phenotypic change in response to several environmental consequences of climate warming.

86-6 GILET, T*; LABOUSSE, S; LAMBERT, P; COMPERE, P; GERNAY, SM; U. Liege, Belgium, Corwave, U. Libre de Bruxelles, Belgium; *tristan.gilet@ulg.ac.be*
Multiscale tarsal adhesion kinematics of freely-walking dock beetles
In this experimental study, living dock beetles are observed during their free upside-down walk on a smooth horizontal substrate. Their weight is balanced by the adhesion of hairy structures present on their tarsomeres. The motions involved in the attachment and detachment of these structures were characterised by simultaneously imaging the beetle from the side at the body scale, and from the top at the scale of a single tarsal chain. The observed multiscale three-dimensional kinematics of the tarsi is qualitatively described, then quantified by image processing and physically modelled. A strong asymmetry is systematically observed between attachment and detachment kinematics, both in terms of timing and directionality.

P1-174 GILLESPIE, CE*; PECHENIK, JA; PIRES, A; Dickinson College, Tufts University; *gillespc@dickinson.edu*

Effects of Temperature and pH in Larval and Juvenile Development in the Marine Gastropod Crepidula fornicata

Rising atmospheric CO_2 levels are associated with warming and acidification in coastal marine ecosystems, with impacts that are especially acute for marine calcifiers. We have investigated the effects of pH and temperature on larval growth, time to metamorphic competence, and juvenile growth in the marine gastropod *Crepidula fornicata*. Larval growth rates and acquisition of competence for metamorphosis were measured in 4 replicate cultures in each of 4 treatment groups, representing all combinations of pH 7.6 and 8.0, at either 20° or 24°C. Higher pH and higher temperature additively increased larval growth, and larvae became competent for metamorphosis sooner at higher temperature and at higher pH, but there was no significant interaction of pH and temperature on larval growth rates or on frequencies of metamorphosis. After metamorphosis, juveniles from each larval condition were individually cultured at either pH 7.6 or 8.0. Temperature was not controlled during juvenile growth; all individuals were exposed to the same ambient laboratory temperatures of 21°-23°C. Juveniles grew at similar rates in both pH conditions. However, juveniles reared at 24°C as larvae grew more slowly than their siblings that had been reared at 20°C as larvae, during the first 7 days of post-metamorphic growth. This difference was no longer apparent by 11 days after metamorphosis for juveniles derived from most larval conditions. However, slower growth persisted in juveniles that had been reared as larvae at 24°C and pH 7.6, and kept at pH 7.6 after metamorphosis. This result is consistent with related studies that show persistent effects of larval pH experience that emerge under some juvenile growth conditions. (Supported by NSF 1416690.)

P3-105 GILLY, WF*; KIER, WM; DRAKE, OV; GREGG, L; Stanford Univ., Univ. North Carolina, Chapel Hill, Cal Poly San Luis Obispo; *lignje@stanford.edu*

Excitability of Transverse Tentacle versus Arm Muscle Fibers in the Squid, Doryteuthis opalescens

Tentacles and arms of squid differ in that the two tentacles extend in 15-30 ms during prey capture, whereas the eight arms undergo slower bending without changing length. Fibers of the transverse muscle mass that generate tentacular extension are cross-striated and have a shortening velocity 10-fold higher than the obliquely-striated fibers in the transverse muscle mass of the arms that generate slower movements. Given the explosive elongation of tentacles, we hypothesized that electrical excitability of transverse tentacle fibers would be characterized by an all-or-nothing action potential mechanism. Whole-cell patch voltage-clamp experiments were carried out on enzymatically dissociated muscle-fiber fragments (5-20 pF capacitance) from small blocks of transverse muscle dissected from tentacles and arms. Na current (I_{Na}) density (normalized to cell capacitance) in tentacle fibers was 10-fold higher than that in arm fibers. I_{Na} was tetrodotoxin-sensitive and similar to that in squid giant axons. Voltage-dependent I_K density was about 4-fold higher in tentacle fibers than in arms, and kinetics of activation and inactivation were slower in tentacles. In general, neither fiber type had significant I_{Ca}, although fibers of both types occasionally showed non-inactivating I_{Ca}. Under current-clamp conditions only transverse tentacle fibers generated all-or-nothing action potentials. Excitability of transverse tentacle fibers is thus appropritate for a rapid tentacular strike.

10-1 GIRALDO, YM*; DICKINSON, MH; California Institute of Technology; *ygiraldo@caltech.edu*

Neural basis of sun-like navigation in Drosophila

Insects exhibit impressive navigational abilities, from long distance migrations of monarch butterflies to path integration of desert ants in the genus *Cataglyphis*. Although not generally considered migratory, mark-recapture experiments indicate that *Drosophila* can cover 10 km of open desert in perhaps as little as a few hours without stopping to refuel. This impressive feat required flies to adopt a fairly straight path, likely accomplished by visually guided navigation using celestial cues. Using a flight simulator with machine-vision wing tracking, we found that tethered *D. melanogaster* can use the position of a simulated sun to fly straight, and individuals adopt arbitrary headings. A preferred heading is maintained over short intervals, but fidelity decays as the time between flights is increased. Furthermore, we found that by restricting visual stimuli to one-half of the arena during flight, we could bias subsequent headings towards the direction of the initial stimulus. Recent advances in our understanding of *Drosophila* central complex function during navigation reveal that wedge neurons of the ellipsoid body, a homologous structure to the lower division of the central body in other insects, are important for visually guided locomotion both in walking and flying flies. Using 2-photon functional imaging we found that the activity of these neurons tracks the position of a simulated sun, similar to results obtained from flies responding to other visual objects. Genetic silencing of wedge neurons using the inwardly rectifying potassium channel KiR2.1 appears to restrict the distribution of flies' headings. Future experiments on these and other neuron types in the central complex are likely to reveal neural elements that are highly conserved in insect navigation.

33-1 GIRARD, MB; KASUMOVIC, MM; ELIAS, DO*; UC Berkeley, University of New South Wales; *doelias@berkeley.edu*

Multimodal communication in peacock spiders: Examining the role of visual and vibratory signals in Maratus volans courtship

A long-standing goal for biologists has been to understand how female preferences operate in natural systems. Of particular interest are systems where males have evolved complex, multi-component signals produced using different sensory modalities. We examined the peacock spider *Maratus volans*, where exceptionally colorful males perform elaborate dances and vibratory songs to entice females to mate. We ran a series of mating trials to examine male signals and the features of signals that predicted mating success. Next, we ran a set of trials where we manipulated the visual and vibrational environment to examine the role of color and vibratory songs. Overall, our results suggest that different signal types have different functions and that females base their mating decisions primarily on the basis of dances and much less so on color or vibratory aspects of displays.

P2-35 GLASER, FL*; CORDOVA, KL; HACK, NL; JOURNEY, ML; RESNER, EJ; HARDY, KM; BECKMAN, BR; LEMA, SC; Cal Poly, San Luis Obispo, NOAA Northwest Fisheries Science Center; *slema@calpoly.edu*

Response of the insulin-like growth factor (IGF) system to nutritional stress in juvenile copper rockfish Sebastes caurinus

Nutritional stress affects somatic growth in part by altering the expression of hormones in the somatotropic endocrine axis such as insulin-like growth factor-1 (Igf-1). In this study, we examined how the Igf system responds to variation in food availability in juvenile copper rockfish, *Sebastes caurinus*, a nearshore Pacific rockfish species important for both recreational and commercial fisheries. By regulating food rations, we created groups of copper rockfish with higher or lower growth rates. After 140 d under these rations, some rockfish from both growth treatments were fasted for 12 d, while other fish continued to be fed. As expected, juvenile rockfish in the high ration treatment grew more quickly (avg. length specific growth rate [SGR]: 0.114% per d) than those in the low feed treatment (SGR: 0.055% per d), so that high ration fish were larger in mass and length and had a higher body condition (k). Fish from the high ration treatment also had higher blood glucose concentrations than those under low ration, and fish from both ration treatments that were fasted had lower blood glucose than those that continued to be fed. Rockfish that grew more slowly from reduced rations had a lower relative abundance of gene transcripts encoding *igf1* in the liver, but elevated hepatic mRNAs for Igf binding proteins *igfbp1a* and *igfbp1b*. Fasting decreased the abundance of *igf1* mRNAs in the liver in both growth groups, while concurrently increasing *igfbp1a* and *igfbp1b* mRNAs over 3-fold. These results point to changes in Igf signaling as contributing to the reduced growth that Pacific rockfishes exhibit under conditions of limited food abundance.

P3-156 GLASS, J.*; STAHLSCHMIDT, Z.R.; Univ. of the Pacific; *jordan_glass84@yahoo.com*

Developmental plasticity of sexually selected traits in complex environments

Animals must respond to complex environmental conditions by effectively allocating resources toward different fitness-related traits, including those associated with sexual selection. However, when faced with challenging conditions (e.g., thermal or nutritional variability), the partitioning of resources among these traits may not be equal. For example, non-ideal developmental conditions may speed development at the expense of body size. Typically, studies examine the plasticity of trait-trait tradeoffs by manipulating (at most) a single environmental variable, such as food availability or temperature. However, environments are complex, and many environmental factors vary simultaneously. Thus, we used male sand field crickets (*Gryllus firmus*) to investigate how multiple environmental variables influence the developmental plasticity of a number of fitness-related traits (e.g., survival, growth rate, developmental time, body size, and locomotor musculature), some of which are associated with sexual selection. For example, relative to their smaller counterparts, *G. firmus* males with larger body size and larger mandibles are more likely to win male-male contests and achieve fertilization. We factorially manipulated variation in food availability and temperature fluctuation because these two abiotic factors can naturally covary and often indicate the quality of a given environment (e.g., favorable environments may be characterized by unlimited food availability and stable temperature). Our results will provide insight into the dynamics by which animals prioritize important traits due to a range of developmental environments—from hypothetically low quality (low food availability and fluctuating temperature) to high quality (high food availability and stable temperature) conditions.

11-4 GLASS, J.R.*; STAHLSCHMIDT, Z.R.; University of the Pacific; *jordan_glass84@yahoo.com*

Do complex environments drive the developmental plasticity of fitness-related traits and a tradeoff between flight and fecundity?

Animals regularly deal with environmental changes by effectively allocating scarce resources toward somatic and reproductive tissues. However, when faced with challenging conditions, the partitioning of resources among these traits may not be equal. Typically, studies examine the plasticity of tradeoffs by manipulating (at most) a single environmental variable, such as food availability or temperature. However, many environmental factors vary simultaneously. Thus, we investigated how multiple environmental variables influence the developmental plasticity of a number of fitness-related traits (e.g., survival, growth, and body size), as well as an important tradeoff between investment into flight musculature and fecundity. In female sand field crickets (*Gryllus firmus*), we factorially manipulated variation in food availability and temperature fluctuation because these two abiotic factors can naturally covary and often indicate the quality of a given environment (e.g., favorable environments may be characterized by unlimited food availability and stable temperature). Our preliminary results indicate a tradeoff (a negative relationship) between flight musculature and fecundity, and that increased food availability promotes investment into ovaries at the expense of reduced investment into flight musculature. Other early results indicate that fluctuating developmental temperatures increase growth and developmental rate. Together, these results indicate that each environmental factor influenced a different set of fitness-related traits and/or tradeoffs thereby highlighting the need to examine the effects of more than one factor on animal traits and trait-trait interactions.

125-2 GLEASON, LU*; BURTON, RS; California State University, Sacramento, Scripps Institution of Oceanography, University of California, San Diego; *lani.gleason@csus.edu*

Regional patterns of thermal stress and constitutive gene expression in the marine snail Chlorostoma funebralis in northern and southern California

Southern California (USA) populations of the intertidal snail *Chlorostoma funebralis* occupy warmer climates than northern California populations, and southern populations are more thermally tolerant and have unique transcriptomic responses to heat stress compared to northern populations. To investigate how climate affects body temperature patterns for *C. funebralis*, iButton temperature loggers encased in empty *C. funebralis* shells (robosnails) were deployed at three northern and three southern California sites for 1.5 months in the late summer and early fall of 2014, typically when maximum annual temperatures are reached. Measurements reveal that southern, thermally tolerant populations experience higher average daily maximum and absolute maximum temperatures than northern, less tolerant populations, and that robosnails in southern, but not northern, California exceeded temperatures that cause 100% mortality. Similarly, the probability of a site reaching 27 °C, the temperature that induces the heat shock response in *C. funebralis*, is three times higher at the southern compared to the northern sites. To determine whether these exposures to stressful temperatures are related to gene expression differences, we then tested for correlation between the probability of reaching 27 °C and the constitutive (non-induced) expression of genes previously implicated as pre-adapted in southern California populations. We identified 222 genes (including 14 involved in ubiquitin protein degradation, a response to heat stress) with a significant correlation. The results demonstrate how combining in situ temperature and transcriptome data can increase our understanding of thermal adaptation and better inform predictions regarding the impact of future climate change.

59-3 GLEASON, LU; STRAND, ES; HIZON, BJ; DOWD, WW*; California State University, Sacramento, Loyola Marymount University, Washington State University; *wes.dowd@wsu.edu*
Post-settlement plasticity of thermal tolerance and energetic constraints in juvenile mussels (Mytilus californianus)
Complex life cycles characterized by uncertainty at transitions between larval/juvenile and adult environments could favor irreversible physiological plasticity at such transitions. To assess whether thermal tolerance of intertidal mussels (*Mytilus californianus*) adjusts to post-settlement environmental conditions, we collected juveniles from their thermally buffered microhabitat from high and low-shore locations at cool (exposed) and warm (protected) sites. Juveniles were transplanted to unsheltered cages at the two low sites or common gardened. Juveniles transplanted to the warm site for one month in summer had higher thermal tolerance, regardless of origin site. In contrast, common-gardened juveniles from all sites had lower tolerance indistinguishable from exposed-site transplants. After six months in the field plus a common garden period, there was a trend for higher thermal tolerance at the protected site, while reduced thermal tolerance at both sites indicated seasonal acclimatization. Thermal tolerance and growth rate were inversely related after one but not six months; protected-site transplants were more tolerant but grew more slowly. In contrast to juveniles, adults from the low-shore exposed and protected sites retained differences in thermal tolerance after one month of common gardening in summer. Both irreversible and reversible forms of plasticity must be considered in organismal responses to changing environments.

P2-262 GODFREY, R.K.*; GRONENBERG, W.; University of Arizona; *rkeatinggodfrey@email.arizona.edu*
Trail-following behavior and antennal lobe anatomy in Dolichoderine ants
Ants rely on a combination of recent experience (private information) and signals from conspecifics (social information) to locate and exploit food resources. Theoretically there exists a tradeoff between the relative valuation of these kinds of information, as a strong bias for social information can lead to rapid exploitation of resources, but may result in non-optimal or inflexible resource selection. To better understand how reliance on social cues versus other forms of information affects foraging patterns, we measure trail following behavior and social interactions in two related species of species of Sonoran desert ants of the subfamily Dolichoderinae. Both species, *Forelius mccooki* and *Dorymyrmex bicolor*, form large colonies and use a combination of mass recruitment and individual retrieval in foraging. Here, we quantify subtle differences in social information use and autonomous foraging behavior between these species. To assess whether patterns of social information use correlate with investment in olfactory processing, we compare the antennal lobe of these two species with one another and with those of Dolichoderine species that rely more heavily on individual foraging behavior.

60-4 GOEPPNER, SR*; PEARCE, ME; BEATY, LE; LUTTBEG, B; Oklahoma State University, Trent University; *scott.goeppner@okstate.edu*
Transgenerational Responses of Snails to Fish Predators
Physa snails change their shell morphology within and across generations based on the types of predators in their environment. It is unclear, however, the degree to which *Physa* morphological plasticity varies spatially and whether parental effects are generalized across predators. To address these questions, we used a predator-prey system consisting of Physa snails, and a fish predator, *Lepomis macrochirus* - the bluegill sunfish. F0 snails were collected from two sites: one containing bluegill sunfish and the other without., Eight maternal lines of snails (F1) were reared from each site. From each line, half the F1 snails were exposed to sunfish cues and the other half were exposed to control cues, i.e. water. After four weeks, we collected eggs for the F2 generation and reared them in the absence of cues. For each generation, at four weeks we measured snail crush resistance, size, and shape. In the F1 generation, snails from the site with fish were rounder and more crush resistant than snails from the site without fish, and, in contrast to control-reared snails, snails from both sites were more crush resistant and rounder when they were exposed to fish cues. Unexpectedly, however, we found no evidence that shell roundness was directly related to crush resistance. In the F2 snails, we again found that snails from the site with fish were more crush resistant than snails from the site without fish, but the offspring of snails exposed to fish cue were less crush resistant than those exposed to control cue. Overall, we conclude that parental effects in *Physa* snails differ depending on predator type. We also found evidence of site-specific shell morphology that may help the snails resist local suites of predators.

P2-64 GOEPPNER, SR*; KOCH, RW; Oklahoma State University; *scott.goeppner@okstate.edu*
Life history traits of a freshwater snail with acanthocephalan and trematode infections
Parasites are known to affect the life history of their hosts, including lifespan, fecundity, and maternal investment in offspring. Previous work on freshwater snails has shown that trematode infections reduce host fecundity and survival. In this experiment, we considered a novel snail-acanthocephalan system and compared the effects of acanthocephalan and trematode infection on host survival and fecundity. To do this, we measured life history traits of 36 field caught *Helisoma* sp. snails in the lab, including their survival, egg production, and size. After the snails died, they were dissected and examined for acanthocephalans and trematodes. To determine if there were potential hereditable differences between snails infected and not infected with acanthocephalans, we raised the offspring of the wild caught snails in the lab and measured their egg production and size. We found no significant difference in egg production, size, or survival between snails infected and uninfected with acanthocephalans. However, snails with trematodes laid fewer eggs, were larger, and had lower survival than uninfected snails. The offspring of snails infected with acanthocephalans did not differ in size or egg production from the offspring of uninfected snails. Trematode and acanthocephalan infections were not independent; the majority of snails were co-infected or uninfected. These results suggest that acanthocephalans do not reduce snail fecundity or survival, while trematodes do. High co-infection rates could suggest that acanthocephalans and trematodes are encountered together in the field, older snails have a high probability of encountering both parasites during their life, or that infection with one parasite increases the susceptibility to other parasites.

P1-245 GOFF, CG*; GABOR, CR; Texas State University; *goff@txstate.edu*
Applying Conservation Physiology to Examine the Effects of Temperature and CORT on Amphibians
Temperatures have been rising due to climate change and other anthropogenic changes have been altering the environment. Increased temperatures and other environmental changes may affect an organism's ability to maintain homeostasis. Monitoring physiological responses to stressors in individuals can provide an early-warning indicator of stressed populations. During early development in amphibians, changing conditions can increase stress, affecting developmental rate and fitness. Temperature changes can decrease immunity in amphibians. Further, stressed amphibians release corticosterone (CORT) into water and can uptake exogenous CORT. We compared the effects of temperature and the addition of exogenous CORT on the stress response and body condition of *Rana berlandieri* tadpoles across 4 treatments: 1) 19°C with no CORT, 2) 19°C with 125nM exogenous CORT, 3) 27°C with no CORT, and 4) 27°C with 125nM exogenous CORT. We used a water-borne hormone assay to measure CORT release rates after 7 days in each treatment. We found that tadpoles exposed to higher temperatures had reduced body condition compared to the control, but the addition of exogenous CORT did not affect body condition. We also found that both temperature and the addition of exogenous CORT affected CORT release rates. Our results indicate that both temperature and exogenous CORT induce physiological stress in *Rana berlandieri*. CORT in and of itself is not likely mediating the decline in body condition. These results indicate that changing environmental variables may result in multiple stressors and could lead to reduced population viability. Monitoring physiological responses to multiple stressors will be key to understanding mechanisms underlying the response to environmental change and predicting its effects across populations.

18-7 GOH, AHY*; SARANATHAN, V; Yale-NUS College, Singapore; *adam.goh@u.yale-nus.edu.sg*
45 Million Years of Structural Color in Fruits of Elaeocarpus
Fruits of the genus *Elaeocarpus* (Elaeocarpaceae) are notable for exhibiting structural coloration, but little is known about the evolutionary basis of this relatively rare trait in plants. Further, ultrastructural knowledge of these structurally colored fruits remains limited. We reconstructed the evolutionary history of structural color in Elaeocarpaceae using published phylogenetic hypotheses based on plastid and nuclear sequence data. We used scanning and transmission electron microscopy (EM), UV-VIS-NIR spectrophotometry, and theoretical optical modeling to confirm the structural origin of the blue structural color, as exemplified by the Blue Quandong (*E. angustifolius*). EM analyses shows that structural color in *Elaeocarpus* fruits is typically produced by a disordered multilayer ultrastructure within the epidermis, with theoretical modeling of the ultrastructure consistent with the measured reflectance spectrum. Ancestral state reconstruction reveals that the structural coloration trait is likely ancestral to this genus, with about 14 losses and 4 gains. Phylogenetic regression analyses also reveals that the presence of structural coloration is significantly correlated (Pagel's λ 0.68, $P < 0.001$) with the extant geographical range of cassowaries (*Casuarius* spp.) but not with other ecological factors such as elevation, fruit size or shape, suggesting dispersal services provided by cassowaries and fruit pigeons (in the Southern Pacific) likely played a key role in both the evolution and maintenance of structural color in this genus. The results of this study can perhaps provide insights into exploitation of sensory preferences in the coevolution of plant-disperser mutualisms in forest ecosystems.

S1-7 GOLD, DA; California Institute of Technology; *dagold@caltech.edu*
The evolution and adaptation of jellyfish in Precambrian oceans
Molecular and geochemical data suggest that the first animals evolved during a period of climate instability and limited ocean oxygenation. The hypothesis that sea sponges—the simplest living animals—predate a uniformly oxygenated ocean has gained support; there is growing evidence for "sponge" biomarkers ~650Mya, and some sponges can survive in extremely oxygen-poor environments. Much less is known about pelagic animals such as jellyfish and ctenophores, which appear to have evolved within a similar window of time as sponges. Here I present ongoing work on the jellyfish *Aurelia*, which provides new insight into the ways early animals might have survived on an inhospitable Earth. Firstly, molecular clocks and gene expression data derived from the *Aurelia* genome support the hypothesis that jellyfish diversified long before the Cambrian. Secondly, by studying growth and tissue regeneration in *Aurelia*, my colleagues and I have discovered a high level of developmental plasticity, which is primarily dictated by the amount of nutrition the animal can obtain. Some of these developmental strategies utilize extremely low levels of oxygen consumption. The results from this work suggest that pelagic, gelatinous animals may have been an important part of Neoproterozoic ecology. Additionally, this work shows how metabolic and respiratory information from early-branching animals could prove useful for calibrating both molecular clocks and geochemical proxies of Earth's biosphere.

21-5 GOLD, MEL*; WEST, AR; GARDINER, AJ; Stony Brook Univ., Carnegie Museum, amyjgardiner.com; *egold@amnh.org*
She Found Fossils: A Kids Book About Women in Paleontology
She Found Fossils is a picture book about the history and present diversity of women in paleontology. It tells the remarkable stories of women all over the world in paleontological careers. We include professors, curators, artists, preparators, outreach specialists, and students. The story behind the creation and successful fundraising is just as interesting as the stories within book itself. We had no difficulty coming up with ideas for kid's books, but meetings with publishers sent us in radically different directions and ended with numerous rejections. Finally, we decided that it was time to take our idea into our own hands, connect with an illustrator independently, and raise the money for publication through crowdfunding. The book is now scheduled for release in December, and will be available in three languages: English, Spanish, and Mandarin. We will also donate copies of the book to schools, libraries, and museums in underserved communities. A major challenge for diversity-fostering material is that the way it gets presented and marketed tends to implicitly narrow its potential target audience and diminish its impact and longevity, which has also been shown to discourage women. We address this by discussing the barriers some of our historical figures faced in simple and direct language, and contrasting these to the present day. Explicit gender-based barriers to education persist in many parts of the world, and we were fortunate to be able to include the stories of some modern, groundbreaking women who have dealt with this exclusion. We hope, by presenting a concrete concept of what marginalization looks like, as well as how some individuals have battled it, to help recast modern STEM fields as more inclusive and diverse than ever.

126-5 GOLDBERG, JF*; FRASER, DF; REZNICK, DN; Univ. of California, Riverside, Siena College; *joshua.goldberg@email.ucr.edu*

Behavioral Adaptations of Trinidadian Killifish to Experimental Introduction of an Intraguild Predator

Intraguild predation (IGP), where two consumer species compete for a shared resource and also prey upon each other, commonly occurs in nature, but ecological theory suggests that this complex interaction can only persist under a relatively narrow range of conditions. A variety of behavioral mechanisms can facilitate the coexistence of intraguild predators, including temporal or spatial specialization. The IGP interactions of Trinidadian killifish (*Rivulus hartii*) and Trinidadian guppies (*Poecilia reticulata*) in the headwater streams of the Northern Range Mountains of Trinidad present an opportunity to test these mechanisms in nature. We experimentally introduced guppies into 4 previously guppy-free, killifish only streams in 2008-2009 to simulate the natural colonization of killifish-only habitat by guppies. We paired experimental introduction reaches with reaches located upstream above barrier waterfalls that provided a killifish-only control. Each stream habitat is naturally divided into pools and riffles. Guppies are diurnal and tend to specialize in pool habitats, so we assessed the hypotheses that killifish would become more nocturnal and lay more eggs in riffle habitats in introduction sites relative to controls to minimize IGP interactions with guppies. We found that killifish significantly changed their diel activity patterns to become more nocturnal in one stream (χ^2_3=17.8, p<0.001). Similarly, introduction killifish laid significantly more eggs in riffles than pools, while control killifish favored pools over riffles for egg laying across all 4 streams (χ^2_1=7.0, p=0.008). Thus, behavioral adjustment of diel patterns and habitat use may reduce antagonistic IGP interactions between guppies and killifish and facilitate coexistence.

35-7 GOMES, G; KÖBERLE, R; VON ZUBEN, CJ; ANDRADE, DV*; Physics Institute of São Carlos, University of São Paulo, Brazil., Depto de Zoologia, IB, Universidade Estadual Paulista. Rio Claro, SP, Brazil., Depto de Zoologia, IB, Universidade Estadual Paulista. Rio Claro, SP, Brazil.; *denis@rc.unesp.br*

Stay Cool With a Drop of Drool: Evaporative Cooling Blowfly Way

Body temperature (T_b) regulation requires the balance between heat gain and losses to the environment and adjusts in metabolic heat production. If T_b is elevated, heat dissipation can be increased by changes in microhabitat selection, body posture, erection or bristling of fur or feathers, and peripheral vasomotor responses. In terrestrial animals, heat dissipation is also assisted by evaporative cooling. Evaporation can occur from humid body surfaces or from watery fluids exposed to the environment by different avenues, for example, by sweating, salivation and licking, and panting. In most insects, evaporative cooling is constrained by their impermeable exoskeleton, while their small size makes them particularly susceptible to heat gain. Herein, we describe a novel thermoregulatory behavior in which the blowfly, *Chrysomya megacephala*, moves tidally a saliva droplet out and then back into the foregut in order to attain the benefits of evaporative cooling. As revealed by infrared thermography, as the saliva droplet is moved outwards, evaporation cools the fluid and, upon its re-ingestion, it cools the fly´s body tissues. Saliva droplet movements are driven by the pharyngeal pump and saliva can be pooled underneath the brain, possibly facilitating brain cooling. The occurrence of the saliva droplet tidal movements is influenced by ambient temperature and relative humidity. The use of a dynamically moved saliva droplet represents an entirely novel modality to interface a watery fluid to the environment in order to attain the benefits of evaporative cooling. Financial support: São Paulo Research Foundation (FAPESP)

P1-206 GOMINHO, B*; SCHILDER, R; Pennsylvania State University, University Park; *bsg5145@psu.edu*

Heat Shock Response in the Flight Muscles of the Endothermic Hawkmoth, Manduca sexta

In many organisms, relatively small changes to their body temperature can lead to thermal destabilization of proteins and lipids, which can affect major organ functions and possibly lead to death. In order to survive, endothermic animals actively and accurately regulate their body temperature, unlike many ectothermic animals, which are at the mercy of the environment. For ectotherms, one mechanism to cope with environmentally-induced changes in body temperature involves the expression of molecular chaperones known as heat shock proteins (HSPs), which can assist in the stabilization of damaged, unfolded proteins. In endothermic insects, such as the nocturnal hawkmoth, *Manduca sexta*, body temperature can vary dramatically on a daily basis, and differences between thoracic (reaching >40°C during hovering flight), and head and abdominal temperatures can be significant. However, it is currently unknown whether these insects initiate a heat shock response in response to highly variable body temperatures, nor how ambient temperature may affect this mechanism. Here we present, what is to our knowledge, the first data on the time series of *M. sexta* flight muscle and fat body heat shock response (i.e. expression of HSP70) to hovering flight at 22°C and 35°C ambient temperatures, and 45°C ambient temperature in the absence of flight.

P3-151 GONZALEZ, SJ*; CARMO, OMS; FANG, JT; KRETSCHMAR, AC; FEEZELL, MK; MAY, MA; VASQUEZ, MC; TODGHAM, AE; TOMANEK, L; Cal Poly San Luis Obispo, UC Davis; *sgonza28@calpoly.edu*

Changes in the Clearance Rate of Mytilus californianus in Relation to Food Availability and Heat Stress

The California mussel, *Mytilus californianus*, will experience increased heat stress and shifts in food availability as a result of climate change. To evaluate the role of sirtuins (NAD-dependent deacylases) as a link between temperature tolerance and food availability, we conducted a study to examine the effects of food, thermal history, and sirtuin inhibition on the response of *M. californianus* to acute heat stress. Mussels were acclimated for 3 wk to a semidiurnal tidal cycle, circadian rhythm, and one of four combinations of maximum emersion temperature (20 or 30°C) and food availability (0.25% or 1.5% mussel dry weight•day^{-1}). We employed a high-resolution sampling regime over 48 h during the end of the acclimation to look at how mussels responded to the various treatments. Clearance rate was measured as the relative fluorescence of the algal particles within a static chamber, spanning 30 m of feeding. At the end of the acclimation, half of the mussels from each group were exposed to sirtuin inhibition, and then all groups were subjected to acute heat stress (33°C) during the subsequent low tide period. We then monitored recovery of the animals over the next 48 h, using clearance rate as a proxy. We predict that mussels previously acclimated to a lower temperature will decrease food intake after experiencing acute heat stress in comparison to those acclimated to a higher temperature. This effect will be more pronounced in the low food treatments. We also predict that sirtuin inhibition will further reduce feeding, as the mussels struggle to recover from acute heat stress (funded by NSF IOS-1557500).

P2-265 GONZALEZ-GOMEZ, PL*; ECHEVERRIA, V; ESTADES, CE; WINGFIELD, JC; GONZALEZ-GOMEZ, Lucia; Univ. of California, Davis, Univ de Chile; *plgonzalezgomez@gmail.com*
Overlapping of Molt and Breeding: an Allostatic Load Perspective
In seasonal environments, natural local cues, such as changes in rainfall and temperature, allow birds to schedule life history stages. In this study using the framework of allostasis, we explored the costs of overlapping molt and breeding in two environments with different degrees of seasonality. In our seasonal environment birds avoid the overlap of breeding and molt, and molt was limited to a defined season, following typical songbird pattern, with both wings symmetrically molted. Under year-round benign conditions and an aseasonal environment, we found overlap of breeding and molt, although the molt was less intense in individuals overlapping than in individuals exclusively molting We also found non-typical molt with asymmetry between wings. In some cases birds retained feathers up to three seasons without replacement. Using the allostatic framework we argue that body condition can function as proxy for the cumulative resources available to an individual, and can better explain why some individuals overlap molt and breeding, and others do not under similar conditions. Thus, we observed that body condition was significantly better in birds that overlapped molt and breeding than in birds that did not.

110-3 GOODCHILD, CG*; LOVE, AL; METZ, A; DURANT, SE; Oklahoma State University; *christopher.goodchild@okstate.edu*
Does exposure to crude oil alter self-maintenance behaviors and immune function in birds?
Individuals integrate behavioral and physiological traits in order to protect themselves from infection. Environmental pollutants may affect a bird's integrated defense system by reducing energy availability for self-maintenance behaviors (e.g., preening) and immune function. The Deep-Water Horizon oil spill released 779 million liters of crude oil into the Gulf of Mexico, and caused an estimated 200,000 bird mortalities. However, this damage estimate does not include sublethal behavioral and physiological effects from exposure to crude oil, and therefore may underestimate the harm of oil spills to avian populations. In this study, we were interested in whether crude oil ingestion impacts self-maintenance behaviors and immune function in birds. To do so, we dosed zebra finches (*Taeniopygia guttata*) daily with either peanut oil (control), or with 3.3 ml/kg or 10 ml/kg of crude oil. We measured white blood cell counts and complement activity on days 0, 7, and 15. We also video recorded the birds during the experiment and analyzed the videos for a suite of activity and self-maintenance behaviors. We found that crude oil exposure reduced activity and resulted in a tradeoff between self-maintenance behaviors. Additionally, our immune function data suggest that crude oil ingestion may cause inflammation. Collectively, our results suggest that exposure to crude oil could increase disease susceptibility, and therefore traditional damage estimates may insufficiently characterize the effects of oil spills on avian populations.

2-4 GOODHEART, J*; BLEIDISSEL, S; SCHILLO, D; STRONG, E; COLLINS, A; CUMMINGS, M; WÄGELE, H; Univ. of Maryland, College Park, University of Wuppertal, Museum Alexander Koenig, National Museum of Natural History, National Systematics Laboratory, Museum Alexander Koenig; *jagood@umd.edu*
Comparative morphology and evolution of the cnidosac in Cladobranchia (Gastropoda: Heterobranchia: Nudibranchia)
Shell-less gastropods are known to use multiple defensive mechanisms, including internally generated or externally obtained biochemically active compounds and structures. Within Nudipleura, a group of nudibranchs called Cladobranchia possess such a defense: the ability to sequester cnidarian nematocysts - small venom-filled capsules that can be discharged into the tissues of other organisms. This ability is distributed across ~600 species within Cladobranchia, and many questions still remain in regards to the comparative morphology and evolution of the structure that houses the nematocysts, called the cnidosac. In this research, we use histological techniques to describe the cnidosac morphology across all groups in Cladobranchia in which it has been identified, and discuss this variation in a phylogenetic context. Overall, we find that the length, size and structure of the opening to the cnidosac can vary more than expected based on previous work, as can the structure of the exit and the musculature surrounding the cnidosac. There are also few clear evolutionary patterns in relation to this variation. The sequestration of nematocysts has originated twice within Cladobranchia based on the phylogeny presented here (within Hancockiidae and Aeolidida), but low support for long branches at the base of Aeolidida results in low confidence in this reconstruction. Additionally, the presence of a sac at the distal end of the digestive gland may have originated prior to that of the sequestration of nematocysts. This study provides a more complete picture of the variation in, and evolution of, morphological characters among nematocyst sequestering taxa in Cladobranchia.

115-6 GOPINATHAN, A*; SHYAMAL, S; DURICA, DS; VIT University, Univ. of Oklahoma; *ganilkumar@vit.ac.in*
Studies on ecdysteroid hormone, its receptor gene (EcR) &its expression related to growth & reproduction in decapod crustaceans
The grapsid crab M. messor exhibits definite season dependent patterns of programming of molting and reproduction while Aug-Dec is devoted for breeding activity, Jan-May season is devoted for both molting and breeding. Jun-Jul however is characterized by molt reproductive repose; ovaries of the entire population would be inactive during Jun- Jul season, with no signs of yolk deposition and the entire population would remain in intermolt during this season. The ultrastructural and immunohistochemical (IHC) studies reveal that YO activity in M. messor is at its peak in premolt animals during Jan-May season. These results are being compared with the results of the ecdysteroid titer in relation to various seasons of the year and also pertaining to growth and reproduction. During the breeding season on the other hand the activity was much less than what was registered in premolt crabs. The RIA of the ecdysteroid level revealed the existence of a correlation between ecdysteroid levels and the YO activity. The ecdysteroid nature of the secretion was ascertained through IHC studies. We also report the sequence information on the DNA Binding Domain (DBD), linker (D domain) and Ligand Binding Domain (LBD) of M. messor ecdysteroid receptor (MmEcR) gene. We have also measured MmEcR mRNA transcript levels in the ovary and the hepatopancreas throughout the annual cycle, with special reference to seasons of molt and reproduction. MmEcR expression in both the tissues is found to be at its peak (<0.05) in late premolt crabs (Jan/May), implicating a possible ecdysteroid role in reproduction in M. messor.

P1-242 GORMALLY, BM*; RAMOS, S; ROMERO, LM; Tufts University; *brenna.gormally@gmail.com*

Examining how recovery periods during chronic stress impact physiology and behavior in Passer domesticus

While it is known that chronic exposure to noxious stimuli can result in detrimental effects, we still lack a complete understanding of how specific factors influence the transition from the beneficial, acute response into the chronic, damaging one. In this study, we used house sparrows (*Passer domesticus*) to test a) whether brief recovery periods can relieve this wear and tear, and b) whether these periods influence responses to subsequent bouts of chronic stress. Birds were randomly assigned to one of three treatment groups that were permitted either 0 hours, 24 hours, or 72 hours of recovery following 4 days of a repeated stress protocol. Birds were then subjected to an additional 4 days of a repeated stress protocol. Blood samples were taken prior to the start of the initial stress protocol, after the recovery period, and at the end of the final stress protocol and assayed for baseline, stress-induced, negative feedback strength, and maximum capacity of corticosterone (CORT). Video samples were also taken to quantify changes in the neophobic response. We predicted that birds that were permitted longer periods of recovery would regain negative feedback strength and capacity, and maintain their neophobic responses. Changes in baseline and maximum CORT capacity were independent of recovery period throughout the entire experiment. Stress-induced CORT was reduced most dramatically for the 24-hour recovery group. Negative feedback strength unexpectedly remained the same for the 24-hour group, however was attenuated for the 0 and 72-hour groups over the first two sample points. Neophobia increased nonsignificantly with increasing recovery periods. In sum, these data suggest that brief recovery periods can marginally influence subsequent stress physiology and behavior.

36-3 GORVET, MA*; HIDALGO SEGURA, D; AVEY-ARROYO, J; RICHARDSON, G; BUTCHER, MT; Youngstown State Univ., The Sloth Sanctuary; *magorvet01@student.ysu.edu*

EMG Activation in the Forelimb Musculature of Three-toed Sloths (Bradypus variegatus)

Sloths exhibit below branch walking whereby the limbs are required to support the entire body weight while in suspended posture. Suspensory habits therefore demand great strength and fatigue resistance of the limb flexors; however, the overall skeletal muscle mass of sloths is reduced. It is possible that sloths minimize active muscle recruitment and rely on tensile loading of muscle-tendon units to maintain suspension, thus reflecting a neuromuscular system tuned to conserve energy. Electromyography (EMG) activation was evaluated in a sample of *N*=6 three-toed sloths as an initial test of this hypothesis. EMG was recorded (via fire-wire electrodes) from eight forelimb muscles while sloths performed hanging, inverted walking, and vertical climbing. Our initial observations demonstrate that during hanging, all flexor/extensor muscles display minimal activity except for deltoideus (DELT) and extensor digitorum communis (EDC), which each show small bursts of activation. Most muscles are active during the contact phase of walking and have long bursts that typically occur after the footfall. Although active for a portion of limb contact, DELT, EDC, and triceps brachii have shorter bursts and also show activation during the swing phase. Compared with hanging and inverted walking, the majority of muscles show shorter and larger EMG bursts that may occur before or after each footfall during climbing. The exceptions to these activation patterns when sloths climb are that the biceps brachii and pectoralis superficialis exhibit sizable bursts with long burst durations. Additional evaluations will include quantification of EMG burst intensity and assessment of motor unit recruitment patterns using wavelet analysis techniques.

P2-135 GOSWAMI, P*; TREIDEL, LA; WILLIAMS, CM; UC Berkeley; *lisa.treidel@berkeley.edu*

Differences observed in timeline of investment in reproduction or muscle maintenance with morph and sex in a wing polymorphic cricket, Gryllus lineaticeps

Life history strategies are characterized by different prioritizations of resource allocation between life history traits including growth, reproduction, activity and somatic maintenance. One's life history strategy is plastic and can shift within and between life stages. Identifying the mechanisms of plasticity in life history tactics is a central issue in the study of life history evolution. The variable field cricket (*Gryllus lineaticeps*) is wing polymorphic; new adults will either have long or short wings along with nonfunctional or functional flight muscles. Maintenance of functional flight muscles trades-off with investment in reproduction. Prior to reaching reproductive maturity, if present, functional muscles must undergo histolysis and become nonfunctional. Here we sought to establish the timeline across which *G. lineaticeps* shift allocation of resources between flight capability (muscle size and status) and reproduction (gonad size) in both male and female, long and short wing adults aged between one and nine days old. While about half of female and male short wings had functional flight muscles on adult day one, by day three, functional muscles were rarely observed, suggesting rapid histolysis in this morph. Most long winged males maintain functional flight muscles until day nine but only half of the long winged females had functional flight muscles at day five. Finally, male gonad mass did not vary with morph or age, while the gonad mass of long wing and short wing females peaked at day seven. Overall, this data sets the stage for further exploration of potential environmental and physiological factors that affect life history tactic plasticity in *G. lineaticeps*.

P1-299 GOULD, F.D.H *; DELOZIER, K.; GERMAN, R.Z.; Northeast Ohio Medical University; *fgould@neomed.edu*

Integrated changes in performance, kinematics, and muscle function during swallowing after sensory nerve lesion in infant mammals

Mammalian swallowing requires the complex coordination of over 50 muscles innervated by multiple cranial and cervical spinal nerves for successful bolus transit. The oropharyngeal and airway sensory signals are critical to airway protection during the swallow, but exact sensorimotor interactions are poorly understood. Six infant pigs were implanted with radio opaque oropharyngeal markers and chronic indwelling electrodes in infra and supra hyoid muscles. Pigs were recorded feeding on milk mixed with barium using high speed videofluoroscopy and simultaneous EMG before and after surgical lesion of the right recurrent laryngeal nerve. Measurements included (1) assessment of swallow performance as airway protection (2) tongue, hyoid, and epiglottal kinematics, and (3) duration and relative timing of EMG signals. We tested the hypothesis that the relationship among kinematics, EMG, and airway protection changed as a function of RLN lesion. Following lesion, the relationship between tongue kinematics and airway protection changed for safe swallows only ($p<0.001$). Unsafe swallows did not change. Duration of firing of the thyrohyoid muscle in safe swallows also changed post lesion ($p<0.001$), with no changes in unsafe swallows ($p=0.05$). The generation of the motor patterns that produce the kinematics that result in safe swallows is compromised by lesion of nerves supplying the larynx, but unsafe swallows are similar pre and post lesion. Sensory signals from the upper airway are necessary for the brainstem generation of appropriate swallowing motor patterns.

23-5 GRACE, JK*; ANGELIER, FA; Texas A&M Univ., College Station, CEBC-CNRS, France; *jkgrace@tamu.edu*
Delayed effect of early-life corticosterone treatment on adult anti-predator behavior and breeding readiness in a common passerine
Acute, short-term effects of early-life stress and associated glucocorticoid upregulation on behavior are widely documented across vertebrates. However, the persistence and severity of these effects are largely unknown for wild species through adulthood. Here, we investigate long-term effects of experimental post-natal increases in a circulating glucocorticoid on antipredator behavior and a hormonal indicator of reproductive readiness in house sparrows (*Passer domesticus*). We manipulate circulating corticosterone concentration in wild, free-living nestlings, transfer fledglings to captivity, and test juveniles and adults for two measures of antipredator behavior: evasiveness during a direct human encounter, and propensity to escape from a risky environment. We also administer a gonadotropin-releasing hormone challenge to adult females and measure luteinizing hormone response as an indicator of breeding readiness. We find no effect of early-life stress hormone manipulation on escape behavior, but a delayed effect on evasive behavior: evasive behavior was compromised in adults but not juveniles, and influenced by current body condition. Early-life glucocorticoid manipulation also interacted with mass to influence breeding readiness: treated females that were heavy had a stronger luteinizing hormone response than control females. These results highlight the importance of state-behavior interactions and life stage in assessing long-term effects of early-life stress, and provide rare evidence for delayed effects of early-life stress to adults of a wild avian species.

71-1 GRAHAM, JL*; BAUER, CM; HEIDINGER, BJ; KETTERSON, ED; GREIVES, TJ; North Dakota State Univ, Adelphi Univ, Indiana Univ; *jessica.l.graham@ndsu.edu*
Accelerated aging as a cost of early reproduction in a wild, free-living songbird
Earlier breeders in the temperate-zone often have higher reproductive success than those that breed later in the season, yet few individuals breed early. Early breeding female annual survival has not been found to differ from late-breeding females; however, there may be other long-term costs. We hypothesized that one potential cost for early breeding females is that they may experience accelerated aging. Telomere dynamics are increasingly used as a biomarker for studying biological aging. Telomeres, the repetitive DNA sequences on the ends of chromosomes, serve as a proxy for biological aging because they shorten with age and in response to oxidative stress. Breeding early may increase exposure to stressors, such as cooler temperatures and extreme weather events. We utilized historical nesting records and blood samples of 106 female Dark-eyed Juncos (*Junco hyemalis*) between 1990 and 2016 to test whether breeding early in the season is associated with greater rate of aging as reflected in higher telomere loss. Our data show that earlier breeding females exhibited greater telomere loss over the following year compared with later breeding females. These findings indicate that biological aging may be a significant cost to early reproduction that may prevent the majority of individuals from breeding early, despite the apparent adaptive value of early breeding.

P1-135 GRAHAM, NR*; PECK, RW; GILLESPIE, RG; University of California, Berkeley , Hawaii Cooperative Studies Unit, University of Hawaii at Hilo; *n.graham@berkeley.edu*
Species Delimitation and Phylogeography of Endemic Hawaiian Parasitoid Wasps: Genus Spolas (Hymenoptera: Ichneumonidae)
Parasitic Hymenoptera are one of the most successful and least understood insect radiations. Their extreme diversification is often linked to specialization on particular arthropod host species. The genus *Spolas* Ashmead 1901 is endemic to the Hawaiian Islands and is the only representative of the subfamily Anomaloninae in Hawaii. Although now largely restricted to relatively intact native habitat, it is one of the most abundant groups of endemic Ichneumonidae on the archipelago. Little attention has been given to *Spolas* since Ashmead (1901) and Perkins (1910) first described the fauna. There are currently eleven described species, however, characters used to identify species within this group are highly variable and descriptions of the fauna are surely incomplete. Here we use specimens collected throughout the Hawaiian archipelago over the past 15 years to construct a phylogeny and identify colonization patterns. We performed next-generation amplicon sequencing of two mitochondrial loci, cytochrome b (cyt b) and cytochrome oxidase I (COI), and two nuclear loci, ribosomal subunit 18s and wingless, to construct a phylogeny of *Spolas*. We examine phylogeographic patterns indicating how Spolas has diverged across the archipelago.

77-1 GRAHAM, MA*; EARLEY, RL; BAKER, JA; FOSTER, SA ; Clark University, University of Alabama; *megraham@clarku.edu*
Regional Differentiation of the Stress Axis in Wild Maternal Stickleback Fish and Transgenerational Effects
Hormonal systems enable individuals to maintain homeostasis in the face of environmental challenges, linking environmental variability with variation in behavior and life history traits within an individual. Additionally, information about the environment can be conveyed by maternal hormones to influence offspring phenotypes. We take advantage of the adaptive radiation of the threespine stickleback fish, *Gasterosteus aculeatus* , to ask how environmental differences among populations influence this signaling process in eight populations from southcentral Alaska and southern British Columbia. In these regions, oceanic stickleback have repeatedly colonized freshwater habitats following the last glacial recession, permitting assessment of phenotype shifts from regional, oceanic ancestral surrogates to locally adapted freshwater forms. Here we evaluate natural variation in maternal cortisol and its effects on offspring characteristics. Plasma cortisol levels of ovulated, wild females were measured immediately post capture and an hour after a stressor. Clutches were split for measurement of cortisol and to fertilize for offspring production. Fry were reared under identical laboratory conditions across populations. We provide evidence of regional differences in maternal plasma, egg, and offspring cortisol levels, as well as fry growth and feeding performance. We examine possible reasons for regional differences in the plastic responses of hormone systems, transgenerational consequences of those responses, and the evolutionary trajectories under divergent selective regimes in the two regions.

P1-15 GRAHAM, M*; JAYNE, BC; SOCHA, JJ; Virginia Tech, Univ. of Cincinnati; *grahmich@vt.edu*

Gap distance affects the behavior and precision of movement of flying snakes

In arboreal habitats, gaps in the substrate present challenges for animal locomotion. Whereas most snakes use a cantilevering behavior to cross gaps, flying snakes of the genus *Chrysopelea* also have the ability to jump. To investigate how the snake's locomotor patterns change with gap distance, we recorded four snakes (*Chrysopelea paradisi*) crossing different gap distances between two artificial branches using a six-camera motion-capture system (100-150 fps; Vicon) and 3 videocameras (120 fps; GoPro). Snakes used a progression of behaviors to cross gaps, beginning with a cantilever for gaps up to 50% SVL. After 60% SVL, looped jumping behaviors predominated. However, all dynamic behaviors involved an initial cantilever period, in which the snake extended 15-50% SVL of the anterior body into the gap before forming the loop. The two types of jumping behaviors involved either a "symmetric" or an "asymmetric" loop. The asymmetric loop was similar to the J-loop used in gliding takeoffs, with the head dropping below the branch to form a J-shape in both behaviors. In contrast, during symmetric jumps the snake kept its head at the same height as the branches, resulting in a more symmetric, U-shaped loop. Not only did behavior change with gap distance, it also was associated with decreased precision of landing position. At distances where the snakes used both looped and non-loop behaviors (50% to 60% SVL), the standard deviation in the position of the head at landing was 12.2 mm for non-looped and 21.6 mm for looped behaviors. Overall, these results show that snake behavior is tightly correlated with gap size, with increasing gap distance corresponding to increased loop size and larger variation in landing position.

76-2 GRANATOSKY, MC*; LAIRD, MF; HANNA, JB; STILSON, KT; SCHULTZ, JA; WALL, CE; ROSS, CF; Univ. of Chicago, West Virginia School of Osteopathic Medicine, Duke Univ.; *mgranatosky@uchicago.edu*

Stride Variability Underlies Gait Transitions in Tetrapods

For many animals, the transition from walking to running occurs at a specific speed, but it is unclear what factors trigger gait changes. While the most widely accepted function of gait transitions is the reduction metabolic cost, it is not obvious that there is a metabolic trigger signaling animals when to switch gaits. In humans, gait transitions also function to decrease dynamic instability, which, as measured by stride duration variability, increases with speed and results in greater metabolic costs. While these patterns are known in humans, similar studies have not been conducted in other mammals. This study explores the relationships between the energetic costs of locomotion and stride variability at and around the preferred walk/run transition speed in two mammalian species (*Sapajus apella* and *Didelphis virginiana*). For each subject, the preferred walk/run gait transition speed was determined as animals moved quadrupedally on a treadmill. Once the preferred gait transition speed was determined, energetics and stride variability were calculated at 0.045 m/s intervals above and below this speed. In both species, stride variability and energetic cost increased as animals approached the walk/run transition, and subsequently dropped after animals moved into a run. However, the reduction in stride variability was more closely associated with the preferred walk/run transition speed, and the metabolic benefits occurred later. We propose that animals use proprioceptive information to monitor stride variability and trigger gait transitions to maintain dynamic stability. Metabolic efficiency is clearly an important benefit of gait transitions, but reduction in dynamic instability may be the proximate trigger determining when those transitions occur.

P2-98 GRANDE, T C; WILSON, M V H*; BORDEN, W C; Loyola University Chicago, University of Albertaf, Saginaw Valley State University; *mvwilson@ualberta.ca*

The 'Living Fossil' Acanthomorph Fish Genus Polymixia: Osteology, Phylogeny, Diversity, and Systematic Position

An integral step to understanding the evolution of the Acanthomorpha (spiny-rayed teleostean fishes) is identifying their earliest diverging extant members. A major impediment to understanding them is a lack of information about the ten species of the ‘living fossil' genus *Polymixia*, the only survivor of a Late Cretaceous radiation, and the most-often cited primitive acanthomorph genus. Although often used as an outgroup in phylogenetic analyses, its morphological and genetic diversity are poorly understood. The type species *Polymixia nobilis* (Stout Beardfish) and all six species named since 1970 were described on external morphology and meristics. The only osteological treatment was a comparison of another species (*P. lowei*) to the Beryciformes, a group to which *Polymixia* is not closely related. In our interdisciplinary study, we have examined the osteology and molecular phylogeny of all available species of *Polymixia*. A critical first step has been a detailed osteological analysis of the type species, *P. nobilis*, using cleared-and-stained specimens and µ-CT scanning, with comparisons to other species. We obtained new specimens from the type locality of *P. nobilis* and comparative material of other species from throughout the known range of the genus. A second step has been a phylogenetic analysis based on DNA sequences. This yielded evidence for two clades within *Polymixia*, each represented by several valid species, as well as probable species-level synonymies and cryptic species. Importantly, although the phylogenetic position of *Polymixia* is often stated by the authors of broad-scale molecular phylogenies to be controversial or uncertain, our study provides strong evidence for one particular relationship.

P2-132 GRAY, L/A*; COHEN, C/S; Macalester College, San Francisco State University, Romberg Tiburon Center, Department of Biology, San Francisco State University, Romberg Tiburon Center; *lgray@macalester.edu*

Genetic Variation in Elongation factor 1-alpha in Leptasterias Associated with ‘Sea Star Wasting Disease'

The most recent epidemic of sea star wasting disease (SSWD) across the Pacific Northwest has been the most deadly and geographically widespread in the disease's history. SSWD affects many different species of sea stars, prompting questions about how the disease responds to and shapes local genetics in populations that it affects. Previous work on one affected sea star, *Pisaster ochraceus*, has shown that the elongation factor 1-alpha intronic insertion allele (EF1-a), is lethal when homozygous but maintained in populations by heterozygote advantage. In *Pisaster*, individuals that were heterozygous at this locus showed a decreased occurrence of SSWD. In this study, we examine the relationship between EF1-a genetic variation and SSWD in three species of the affected sea star *Leptasterias*. Stars were collected before the onset of the SSWD epidemic as well as during the epidemic. The stars collected during the epidemic were scored for wasting symptoms in the field. Preliminary data suggest that EF1-a intron 4 in *Leptasterias* displays directional selection or heterozygote advantage during wasting conditions. Comparisons of pre-wasting stars from CA (n=19), and wasting (n=10) and non-wasting (n=14) stars from Pigeon Point, CA and the San Juan Islands, WA revealed a shift in allele and genotype frequency from pre-epidemic conditions to during-epidemic conditions. These results provide valuable information to address questions about the impact of severe epidemics on population genetic variation.

119-6 GRAY, LN*; WHITE, BA; WANG, IJ; Univ. of New Mexico, Univ. of California, Berkeley; *Lngray@unm.edu*

Dewlap size and seasonality: revisiting the Fitch-Hillis Hypothesis in Mexican anoles

Anoles represent an impressive New World lizard radiation, with over 400 species currently recognized. Sexual selection is commonly believed to play a role in anole diversification, reflected in the remarkable dewlap diversity exhibited both within and between species. The Fitch-Hillis Hypothesis posits an effect of seasonality on dewlap size--a short and concentrated breeding season leads to larger male dewlaps. Mexico has some of the most extreme environments experienced by anoles and considerable species diversity. Using dewlap size data and observations from throughout Mexico, I test for correlations between dewlap size and seasonality both within a clade of species (silky anoles) that experience diverse habitats and at broader scales across nearly all anoles species in Mexico.

46-5 GREAR, ME*; MOTLEY, MR; SUMMERS, AP; University of Washington, Friday Harbor Laboratories; *mgrear@uw.edu*

Nonlinear Mechanics of Marine Mammal Skin

Modeling the skin and blubber of marine mammals will aid in understanding injury from anthropogenic structures, such as the moving blades of an energy-generating tidal turbine. A material constitutive model model, detailing the mathematics of how a tissue behaves to various loads and forces can be created by using laboratory material tests as input. Previously we used uniaxial tensile testing of seal, orca, and porpoise soft tissue. Cetacean skin showed a stiffness of about 7 MPa and strength of about 2.5 MPa. We now expand to more types of tissue testing, including examination of the shear modulus and bulk modulus. After separating the blubber and skin soft tissues, subsections of each tissue were loaded in a test rig, recording torque and displacement for the duration of an rotational test for shear modulus. Bulk modulus was calculated using a volumetric compression test. These values, in conjunction with previous elastic modulus testing, allow us to explore the nonlinearity of the material and understand the appropriate level of complexity in modeling. Using multiple marine mammals, including seals and toothed whales, we can further understand how similar the skin of these animals is. In harbor porpoise testing, blubber bulk and shear modulus testing indicates that blubber is near to matching isotropic assumptions, while skin does not. In addition to modeling of injury mechanisms, contrasting between these species will allow further understanding of hydrodynamic or kinematic performance adaptations in marine mammals.

P1-22 GREEN, TL*; GIGNAC, PM; Oklahoma State University Center for Health Sciences, Tulsa; *todd.green@okstate.edu*

Ontogeny of Cassowary and Maleo Casques: Differentiating Patterns of Cranial Ornamentation in Birds

Complexly constructed cranial ornaments, consisting of multiple bony partitions (e.g., cranial casques) are common among archosaurs. Yet, the developmental processes and selective regimes that bring about these metabolically expensive and seemingly bizarre structures remains a mystery. Among Aves, this is partially due to contradictory interpretations of cranial osteology, leaving it unclear whether the underlying bones of different casqued birds are arranged in a similar fashion. Here we compare the ontogeny of avian casques, independently derived in paleognathous and neognathous birds, to clarify their constituent parts. Flightless cassowaries (paleognaths) and volant birds such as helmeted guinea fowl, magpie geese, curassows, hornbills, and maleos (neognaths) possess casques of varying shapes and relative sizes. Casque bones can grow rapidly and are obscured by keratin sheathing in early ontogeny and sutural fusion in adulthood, rendering them difficult to study. To evaluate the null hypothesis that avian cranial ornaments possess similar anatomical patterns, we compared the skulls of southern cassowaries (*Casuarius*), maleos (*Macrocephalon*) and their non-casques relatives throughout ontogeny using µCT data. Crucially, sampling neonates and juveniles with incipient casques allowed us to track telescoping elements and measure growth. Although the neonatal skulls in our sample are broadly similar, our results point towards at least two modes of casque ontogeny: (1) disunited, in which a midline chondrocranial element grows slowly and posteriad to buttresses lateral dermatocranial bones, and (2) geminal, in which a rapidly growing casque is built from anteriad right-left dermatocranial constituents only.

69-4 GREEN, B*; GOSLINER, TM; California Academy of Sciences; *bgreen@calacademy.org*

A Tale of Two? Slugs: cryptic speciation and morphological variation in northeastern Pacific Flabellina

Molecular analysis of the nudibranch genus *Flabellina* in the temperate northeastern Pacific has revealed a more complex picture of the genus than previously recognized. The most commonly encountered species in the region, *Flabellina trilineata*, has been described as exhibiting a wide degree of variation in color throughout its geographic range. Molecular studies using the COI, 16S, and H3 markers indicate that *F. trilineata* is a complex of four species. Further complicating this picture, some specimens previously identified as *F. trilineata* are shown by molecular evidence to belong to the closely related species *Flabellina cooperi*. Additional specimens with a variety of color patterns have also been identified by molecular analysis as *F. cooperi*, suggesting that this species, traditionally considered rare, may actually be somewhat common but frequently misidentified.

27-4 GREEN, P.A.*; PATEK, S.N.; Duke University; *patrick.a.green@duke.edu*

Communication and Combat: The Function of Ultrafast, Ritualized Striking in Mantis Shrimp

Theory predicts that animals should resolve conflicts safely, yet many animals use potentially dangerous "weapons" during contests. Behavioral and biomechanical studies can reveal the role of weaponry in contest assessment and resolution. We tested hypotheses addressing assessment and resolution in the mantis shrimp *Neogonodactylus bredini*, which uses raptorial appendages to present visual displays and to deliver high-force strikes during territorial contests. We first tested if displays signaled strike performance and were used to resolve conflicts without dangerous striking. We measured competitor's appendage morphology and maximum strike force, then analyzed size-matched contest behavior. Morphology did not correlate with force, and 33/34 contests involved striking. While displays did not signal performance to resolve contests, competitors exchanged strikes on each other's armored tailplates in a behavior we termed "telson sparring". To test whether telson sparring functions to inflict costs or in assessment of relative ability, we matched contest dynamics to assessment models. Using correlations and a network analysis of behavioral sequences, we found that sparring is used to assess relative ability. Finally, we measured the energetic cost of sparring. We filmed sparring strikes (30-40 kfps), measured strike velocity, and used a biomechanical model to calculate strike potential energy, comparing this to published measures of resting metabolic rate. In preliminary analyses, each sparring strike used ~1% of hourly metabolic rate. Individual differences in the ability to withstand this cost may support honest signaling theory. Overall, these results show how potentially-deadly weapons can function in assessment, suggesting future work on the behavior and biomechanics of weapon use.

142-5 GRESHAM, JG*; EARLEY, RL; University of Alabama, Tuscaloosa; *jdgresham1@crimson.ua.edu*

Fitness consequences of heterozygosity in a self-fertilizing fish

Mangrove rivulus fish exist predominantly as self-fertilizing hermaphrodites but males, which result from hermaphrodite sex change, occur in varying abundances across their geographical range. Levels of heterozygosity and frequencies of outcrossing between hermaphrodites and males also differ among populations, raising the question of why male abundance varies. We hypothesized that heterozygous progeny derived from outcrossing would have higher fitness than homozygous progeny derived from selfing, especially under stressful conditions. We predicted that increased heterozygosity would correspond with lower mortality, higher growth, and greater reproductive success, trends that would be amplified in suboptimal conditions. To test this hypothesis, fish with varying levels of heterozygosity experienced control conditions or stressors common to their native habitat (high/low salinity, tidal flux). High salinity animals showed greater mortality, lower fecundity, and lower rates of sex change than those in low salinity or controls. Tidal animals were consistently smaller and less fecund than controls but mortality was unaffected. There were no treatment-dependent effects of heterozygosity but fecundity decreased as heterozygosity increased. Sex explained a significant proportion of phenotypic variation even prior to sexual maturation. Animals that eventually transitioned to male were significantly larger during the pre-treatment period than those that remained hermaphrodite. Our results suggest that ecologically relevant stressors influence fitness in a heterozygosity-independent manner and, contrary to prediction, heterozygosity confers no fitness advantage. The adaptive advantages of sex change and outcrossing and, ultimately, which factors govern variation in male abundance thus remain open questions.

P3-167 GRIDER-POTTER, N; Arizona State University; *ngriderp@asu.edu*

Dietary influences on head and neck range of motion in Neotropical bats

Very little is known about the functional morphology of the mammalian neck. The primary function of the mammalian neck is to help maintain a stable head and visual field. A steady head is especially important for successful foraging and hunting. Species that rely on different resources should be under different evolutionary pressures with regard to range of motion of the head and neck. I hypothesize that habitual feeding behaviors should affect the maximum range of motion of the axial skeleton. Species relying on mobile, agile food sources should have greater maximum ranges of motion in order to accommodate hunting behaviors. In contrast, frugivorous and nectivorous species should not require large excursions of the head and neck for feeding. As such, these latter species should experience greater head and neck stability both during locomotion and other behaviors. Maximum head and neck range of motion were collected from fifteen species of wild-caught Neotropical bats (n=39) in Orange Walk District, Belize. To collect ranges of motion, individuals were held flush to a table. Using a dowel, the head and neck were manipulated into maximum flexion and extension while maintaining the first thoracic vertebra in a stationary position. Photographs were taken at maximum flexion, extension, and a self-selected neutral position. Angular measurements were taken from the photographs using ImageJ. A phylogenetic tree was constructed from molecular data and used to conduct a phylogenetic ANOVA. Results show that insectivorous species have a significantly larger maximum range of head and neck motion than frugivorous species indicating that dietary behavior is a significant evolutionary pressure on neck function and, therefore, cervical vertebral morphology. This in turn should affect the maintenance of head stability.

67-2 GRIDER-POTTER, N*; ZEININGER, A; Arizona State University, Duke University; *ngriderp@asu.edu*

Head stability and neck function during locomotion in Varecia variegata

The head houses both visual and vestibulocochlear organs that allow an organism to balance, orient, and navigate during locomotion. Maintaining a stable head should be especially important in primates because they walk predominately on compliant substrates in complex arboreal environments. However, the degree to which the head, neck, and trunk remain stable during arboreal walking in primates is unknown. This study tests the hypothesis that the neck helps maintain head stability by mediating the movement of the trunk. We predict that the trunk should have the greatest range of pitch, the head should remain relatively stable with the least pitch, and the neck should have an intermediate range of pitch between that of the trunk and head during walking. In addition, the neck should move opposite the trunk to maintain the position of the head. Three shaved and marked individuals of Varecia variegata were filmed during arboreal and terrestrial quadrupedalism. Markers were digitized using DLT data viewer. Linear mixed models were conducted to account for both variations in stride length and repeatedly measuring the same individual. Results show mixed support for the predictions. During arboreal locomotion, the trunk pitches significantly more than the head and neck. However, the head has a 10o range of pitch while the movement of the neck is negligible. The head is at its inferior-most position at touchdown during arboreal quadrupedalism but moves much less during terrestrial walking. This suggests that the movement of the head is related to visually ensuring substrate position, which is more variable in an arboreal environment. While head stability is required for all types of locomotion, head mobility may be more important when walking on compliant, unpredictable substrates. Supported by NSF BCS-1731142.

69-7 GRIESEMER, C.D.*; GROSBERG, R.K.; MORGAN, S.G.; University of California, Davis; *cdgriesemer@ucdavis.edu*
Things Fall Apart: The Challenges in Maintaining Sibling Cohesion During Larval Dispersal in Marine Environments
Flat porcelain crabs (*Petrolisthes cinctipes*) occupy discrete cobble beaches and mussel beds dotted along the west coast of North America. Adult populations are connected demographically by an ocean-dispersing larval phase resulting in genetic homogeneity across much of the range. However, smaller scale genetic structure may still be at play in this gregariously settling crab, particularly in cohorts of newly settled larvae. Prior observations indicate sibling crabs may be transported cohesively despite a relatively long planktonic duration. Gravid females exhaustively release their brood during a single tide cycle, patchy clusters of porcelain crab larvae are common in pelagic samples, and settling larvae are regularly found in cohorts of 30 or more individuals in the intertidal during peak recruitment. I tested cohorts of porcelain crab settlers from four beaches for greater than expected genetic relatedness using a suite of hundreds of SNPs obtained through traditional RAD-seq. The five total cohorts showed no increased within-group relatedness and the tests detected no sibling or half sibling pairs. Despite the potential for physical and behavioral larval cohesion in this system, marine larvae likely face a number of challenges that break down the association of related individuals over time. Evaluating these challenges within a framework that considers transport processes across variable temporal and spatial scales may help us to understand better the cases where there is evidence of sibling cohesion (e.g. damselfish and spiny lobster) and those cases where we expect no signal of increased genetic relatedness.

56-8 GRIEVES, L.A.*; KELLY, T.R.; BERNARDS, M.A.; MACDOUGALL-SHACKLETON, E.A.; The University of Western Ontario; *lgrieves@uwo.ca*
Sick birds don't smell: Assessing the impact of haematozoan infection on avian preen oil chemical composition
Haematozoan parasites such as avian malaria infect ~ 70% of bird species worldwide. Haematozoa negatively affect host fitness by decreasing reproductive success and survival. Thus, animals should experience strong selection pressure to assess the infection status of potential mates. Indicator models of sexual selection propose that condition-dependent auditory or visual ornaments, such as birdsong and plumage, can advertise infection status. Virtually nothing is known about chemical signaling of infection status in birds, despite much evidence in mammals for odour-based parasite recognition and avoidance, and despite evidence that birds produce, and attend to, odour-producing volatile chemicals in preen oil. We hypothesized that infection by malarial parasites alters the chemical composition of avian preen oil, potentially providing receivers with a chemical cue of health status. To test this hypothesis, we experimentally exposed song sparrows (*Melospiza melodia*) to *Plasmodium* parasites. We used gas chromatography to compare the chemical composition of preen oil from individuals experiencing acute infections, individuals that were exposed to *Plasmodium* but resisted infection, and unexposed control individuals. Perhaps surprisingly, preen oil composition did not differ significantly between groups. Although data from a broader range of parasite strains and host species are needed before chemical signaling of avian malaria can be conclusively rejected, our findings suggest that chemical signaling of haematozoan infection status may be less effective in birds than in mammals.

75-2 GRIFFIN, C*; ANGIELCZYK, K; GRIFFIN, Christ; Virginia Tech, Field Museum of Natural History; *ctgriff@vt.edu*
The Evolution of the Dicynodont Sacrum, and Constraint on the Axial Column in Crown Mammalia
The sacrum—the vertebrae that articulate with the ilium—is the nexus between the axial skeleton and the hindlimb. Reptiles added sacral vertebrae in several ways (e.g., sacralization of trunk vertebrae), increasing from the plesiomorphic 2 sacrals to >20 in some birds. However, apart from early-diverging "pelycosaur"-grade synapsid lineages, little is known of the mechanisms of synapsid sacral evolution. Dicynodont therapsids have a wide range of sacral counts (3-7+), with a trend of increasing absolute number of sacral vertebrae in younger clades. We explored the addition of vertebrae to the dicynodont sacrum and placed these patterns in the broader context of synapsid evolution. We established the identity of each sacral vertebra by the location of sacral rib—iliac articulation, either by direct observation in articulated specimens, or by the location of sacral scars on ilia. The three primordial sacral vertebrae are located dorsal to the acetabulum, with additional vertebrae added to the sacrum anteriorly and posteriorly. Sacral ribs decrease in size in posterior sacral vertebrae in all observed taxa. Using phylogenetic logistic regression, we found a statistically significant correlation between increase in sacral count and larger body size ($p = 0.002$), even given strong phylogenetic signal. Given that the number of presacral vertebrae is largely conserved across Dicynodontia, anterior sacral vertebrae are added by the addition of novel elements anterior to the primordial three. All crown mammals but xenarthrans are restricted to ≤3 sacral vertebrae, and sacrals are added exclusively from the caudal series. This suggests that dicynodonts were able to escape a constraint on patterns of regionalization in the column that was otherwise common in synapsids.

P1-84 GRIFO-HAHN, L.L.*; KIMBALL, M.G.; RUDY, M.G.; JOHNSON, E.E.; BENNETT, D.J.; BREUNER, C.W.; MALISCH, J.L.; St. Mary's College of Maryland, University of Montana, Pitzer College; *jlmalisch@smcm.com*
Facultative Altitudinal Migration and Glucocorticoid Physiology in White-crowned Sparrows
Severe climatic events during the breeding season can induce behavioral responses that favor individual survival at the potential cost of within-season reproductive success. For example, white-crowned sparrows (WCSP) breeding at high elevation can experience heavy snowfall during both pre-breeding territory establishment and during nest incubation. In the Tioga Pass, CA population (~3,000 m), lower elevation refugia in the Mono Basin (~2,000 m) is readily available and facultative altitudinal migration (FAM) during storms is documented. Predictors of FAM occurrence and duration include body condition, fat score, glucocorticoid physiology, and glucose mobilization capacity. Here we document the occurrence of FAM during the early-breeding season over three years (2015-2017) using radio-transmitters and an automated receiving unit. In 2015-2016, which coincided with a period of drought, there were zero cases of FAM among WCSP outfitted with radio transmitters. In 2017 a significant snowfall event occurred on June 11-12, and all eight WCSP with radio transmitters exhibited FAM.The length of time WCSPs were absent from their breeding territory ranged widely from 2,025-6,340 min (34-106 hours). We obtained individual glucocorticoid and glucose mobilization profiles as well as several measures of body condition during pre-storm stress trials. All WCSPs exhibited stress-induced plasma glucocorticoid and blood glucose levels. Interestingly, the rate of glucocorticoid increase was a significant negative predictor of FAM duration; which is consistent with other studies of glucocorticoid mobilization and territoriality in passerines.

P3-66 GRINDSTAFF, JL*; SANDERS, T; Oklahoma State University; *jen.grindstaff@okstate.edu*

Effects of Maternal and Developmental Immune Activation on Telomere Attrition

Both maternal stress exposure and stress exposure during development exert negative effects on the adult phenotype in a range of organisms. However, the mechanisms through which early life exposure to stressors is translated into impaired function in adulthood are unclear. One way in which conditions in the developmental environment may have systemic effects that are particularly evident late in life, and are associated with accelerated senescence, is through an elevated rate of telomere attrition. Telomere shortening is a normal part of cell division, but exposure to inflammation is hypothesized to accelerate the rate of loss. Thus, elevated levels of inflammation, particularly during development, should be associated with increased telomere attrition and reduced survival. Zebra finches (*Taeniopygia guttata*) exposed to an immune challenge during development that was not experienced by the mother prior to egg production, produce higher levels of corticosterone in response to stress in adulthood. Additionally, individuals with higher corticosterone levels have shorter lifespans in captivity. We will present data that test the hypothesis that immune activation during development induces increased telomere attrition. Telomere length and loss rate are related to survival, and the ability to minimize telomere loss and maximize lifespan, particularly in environments that induce higher rates of telomere loss, may be an important factor underlying life history trade-offs.

P3-20 GRIPSHOVER, ND*; JAYNE, BC; University of Cincinnati; *gripshnd@mail.uc.edu*

Visual Contrast Affects Perch Choice of Brown Tree Snakes (Boiga irregularis)

In arboreal habitats, diverse animals encounter discrete choices between branches with variable structure that has predictable consequences for the ease and speed of movement. Many species of snakes are arboreal, and previous studies found that some species use visual cues to choose between alternative destinations when bridging gaps. For example, brown tree snakes prefer destinations that are wider, closer, and along a straighter trajectory, all of which are biomechanically advantageous. Whether attributes of destinations that are unrelated to mechanical demands affect perch preference remains poorly understood. Hence, we manipulated perch color, background color, perch structure, and perch location to test their effects on perch choice of brown tree snakes bridging gaps. For destinations with identical perch structure, gap distance and trajectories (yaw angle = 45 deg), the snakes preferred black perches rather than white perches when the background was white, but the snakes unexpectedly continued to prefer black rather than white perches when the background was black. The following two cases illustrate how a bias for black perches superseded a bias for a mechanically beneficial perch. First, with a white background and identical trajectories, the snakes preferred a black perch with a 47 cm gap rather than a white perch with a 37 cm gap. Second, a wider white perch was not preferred to a narrower black perch. However, a preference for a straighter trajectory persisted even when the destination with 0 deg yaw was white and the black perch required a 90 deg turn. Our results emphasize that visual cues unrelated to the physical structure of surfaces can bias choice and in some cases supersede a preference for mechanically beneficial surfaces. However, such attributes of locomotor surfaces have largely been ignored.

63-3 GROSS, JB*; BERNING, D; ADAMS, H; GROSS, Joshua; University of Cincinnati; *grossja@ucmail.uc.edu*

The genetic lesions associated with regression: A genome-wide search for destructive mutations in the cavefish genome.

The evolutionary mechanisms governing adaptation to extreme environments remain controversial. In the dark and nutrient-poor cave environment, diverse animals around the world trend towards the loss of eyes and pigmentation. These examples of regressive evolution may evolve through direct selection (e.g., energy conservation), indirect selection (e.g., pleiotropic consequences), and/or neutral forces (e.g., genetic drift). Earlier studies in other systems suggested a principal role for *cis*-regulatory changes to essential genes involved in dramatic ecological shifts. Hybridization studies in cave- and surface-dwelling *Astyanax* fish reveals a different pattern of genetic changes, which may imply that regressive loss occurs more frequently through coding rather than regulatory sequence changes. For example, the genes implicated in two Mendelian pigmentation traits (albinism and *brown*) harbor destructive coding sequence changes in the genes *oca2* and *mc1r*, respectively. To determine the identity and frequency of destructive changes in the *Astyanax* genome, we performed a genome-wide search for insertions/deletions ("indels"). We aligned millions of short reads from two ancient cavefish populations (Pachón and Tinaja) and surface-dwelling fish to the cavefish reference genome. This analysis yielded several compelling genetic lesions that were variably present in each population. The majority of indels were discovered in the surface populations, by reference to the cavefish genome. At present, we have validated eight genetic mutations arising from genes encoding both structural proteins and transcription factors. Further functional analysis will illuminate the precise role for these genes in cave adaptation and help inform the genetic mechanisms mediating colonization of extreme environments.

78-3 GROSSNICKLE, DM; University of Chicago; *davegrossnickle@gmail.com*

Jaw Rule: Mammalian Jaw Morphologies Correlate with Diet and Evolve Toward Trait Optima

Although studies commonly examine correlations between tooth shape and diet using taxonomically diverse mammalian samples, comparable analyses of jaw morphologies and diet across Mammalia are rare. This is surprising because mandibular shape may offer considerable insight into the diets and evolutionary histories of mammals, including fossil lineages. Jaw morphologies are expected to correlate with diet due to common functional demands on the masticatory apparatus of taxa with similar diets. I test this prediction by applying phylogenetic comparative methods to linear jaw measurements and dietary information for over 200 modern mammalian species. Results identify several jaw metrics that are significantly correlated with diet even after accounting for phylogenetic non-independence of data. The length between the jaw joint and the angular process is found to be an especially powerful predictor of diet, as it generally increases with greater herbivory. This length reflects the moment arms of the force vectors of the superficial masseter and medial pterygoid muscles, which are particularly important for transverse jaw movements and grinding of plant material. I expand on these findings by examining the evolutionary mode of jaw evolution by comparing the fit of multiple evolutionary models to the morphological data. I find strong support for the hypothesis that there are unique selective regimes associated with herbivory and carnivory. Further, mandibles of herbivorous species appear to have evolved much more rapidly than carnivores toward a trait optimum, suggesting especially strong selective pressures on these taxa. Thus, this study presents novel data concerning jaw correlates of diet across Mammalia and offers new evidence on the macroevolutionary patterns associated with mammalian diets and morphologies.

P3-191 GRULA, C*; BOWSHER, J; YOCUM , G; HEIDINGER, B; North Dakota State University, Fargo, USDA-ARS, Fargo; *courtneygrula@gmail.com*

Aging and Body Size in Solitary Bees

Solitary bees are important pollinators of crops and non-domestic plants. Osmia lignaria is a native, commercially-reared solitary bee used to maximize pollination in orchard crops. In solitary bees, adult body size is extremely variable depending on the nutritional resources available to the developing juvenile. Body size impacts many different aspects of the bee's physiology and behavior including fecundity, longevity, foraging distance, and pollination efficiency. One aspect of body size that has not been studied in solitary bees is its impact on cellular rate of aging. Studies have shown larger individuals age faster than smaller individuals within a species. The aim of this study is to determine the degree to which adult size variation influences aging in O. lignaria. Adult bees from a naturally occurring population were stored in an incubator and their longevity, and mass were recorded. Telomere length was measured using qPCR to determine whether cellular aging occurred over time and whether individuals differed in their rates of cellular aging. There was a large variation of body sizes among individuals, as well as between the different sexes, in the population. The maximum longevity of bees in this study was 34 days, which is longer than the predicted average lifespan in a field setting. These data can potentially be used to predict the rate of aging in bees of differing sizes based on nutritional stress in an agricultural or natural environment.

74-2 GUENTHER, RJ*; MIKLASZ, K; CARRINGTON, EC; MARTONE, PT; University of Washington, University of British Columbia; *guenther.becca@gmail.com*

Macroalgal spore dysfunction: Ocean acidification delays and weakens adhesion

Early life stages of marine organisms are predicted to be vulnerable to ocean acidification. For many macroalgae, reproduction and population persistence rely on spores to settle, adhere and continue the algal life cycle, yet the effect of ocean acidification on this critical life stage has been largely overlooked. We explicitly tested the biomechanical impact of reduced pH on early spore adhesion. At the University of Washington's Friday Harbor Laboratories Ocean Acidification Environmental Laboratory, we developed a shear flume to examine the effect of reduced pH on spore attachment time and strength on two intertidal rhodophyte macroalgae, one calcified (*Corallina vancouveriensis*) and one non-calcified (*Pterosiphonia bipinnata*). We found that reduced pH delayed spore attachment of both species and also weakened attachment strength in *C. vancouveriensis*, but had no effect on the attachment strength of *P. bipinnata*. Our results demonstrate that ocean acidification negatively impacts spore adhesion in two macroalgae, and this may negatively affect macroalgal communities via loss of spore function and viability, regardless of the physiological tolerance of mature thalli.

P1-109 GUERNSEY, MW*; POLLUX, BJ; REZNICK, DN; BAKER, JC; Stanford University School of Medicine, Wageningen University, Univ. of California, Riverside; *mikewg@stanford.edu*

Prolactin expression in the placenta of pregnant Poeciliopsis fishes

The expression of the pituitary hormone prolactin (PRL) is well documented in the placental tissues of pregnant therian mammals. While its exact role in supporting pregnancy is unclear, genomic studies of the prolactin locus during pregnancy have unveiled variation in copy number and placenta-specific transposon-derived promoters, hinting at a critical role. Further, it is unknown whether PRL is expressed at the maternal-fetal interface of other viviparous vertebrates. Here we study *Poeciliopsis*, a unique genus of live-bearing fish that have evolved bonafide placental structures at least three times independently, providing a unique opportunity to study the de novo evolution of placentation. The placentas of these fish contain a maternal follicle component and a fetal component, respectively akin to the decidua and trophoblast of eutherian mammals. We have been surprised to find the expression of fetal and maternal mammalian placenta markers in these fish. Recently, we found expression of PRL in the maternal follicle of *Poeciliopsis turneri*, *Poeciliopsis retropinna*, and *Poeciliopsis prolifica*, each species representing an independent evolution of placentation. Furthermore, we find no PRL expression in the maternal follicle of *Poeciliopsis gracilis*, a non-placental member of this genus. This suggests that PRL has been independently co-opted for placental function within Poeciliopsis multiple times. We are currently investigating whether the expression pattern of the two prolactin genes in *Poeciliopsis*, *Prl* and *Prl2*, differs and if the promoter structure of placental prolactin transcripts is similar to mammalian prolactins. In completing this work we aim to expand our knowledge of prolactin's role in the evolution of pregnancy.

P3-219 GUERRA, VI *; BYRNE, M; HART, MW; Simon Fraser University , The University of Sydney, Simon Fraser University; *vguerracanedo@gmail.com*

Characterization of Gonad Transcriptomes of Two Sea Stars with Differing Modes of Reproduction

Variation in life history traits and mating systems of sea stars make them useful systems for understanding how reproductive variation affects population genetic structure and molecular evolution. Here I compare and characterize the gonad transcriptomes of two closely related sister species from northeastern Australia with striking mating system differences. *Cryptasterina pentagona* individuals are gonochoric broadcast spawners with planktonic fertilization and the potential for strong sexual selection. By contrast, *C. hystera* individuals have similar morphology and natural history to *C. pentagona* (so similar that they were not recognized as a distinct species until their mating system differences were discovered), but are simultaneous hermaphrodites with internal self-fertilization and live birth, and limited potential for sperm competition (because they lack adaptations for sperm transfer between individuals) or sexual conflict (because outcrossing appears to be rare). Gonadal tissue of *C. pentagona* and *C. hystera* were collected from nine individuals to build and sequence RNA-seq libraries. These libraries were assembled with a de novo approach and analyzed with a customized pipeline. I found a ~10-fold difference in genetic diversity between species, which was consistent with other observations of high inbreeding and small effective population size in viviparous, brooding sea stars. The assembled genes included most but not all of the genes expected to be expressed in gametes and to play a role in fertilization (and evolve under sexual selection), including bindin and its receptors. I used a series of population genetic and phylogenetic tests to detect differences between species in the response to selection on coding sequence variation, which were similar to previously documented differences for bindin.

110-4 GUIGUENO, MF*; HEAD, JA; PETERS, L; HANAS, AM; LETCHER, RJ; FERNIE, KJ; McGill University, University of Manitoba, Environment and Climate Change Canada; *melanie.guigueno@mail.mcgill.ca*

Early-life Exposure to a Commonly-used Flame Retardant in Japanese Quail: Effects on the Thyroid System, Growth, and Metabolic Rate

Flame retardants are a diverse group of chemicals, many of which have the capacity to act as endocrine disruptors in birds. Abnormal hormonal signaling can directly influence organismal oxygen consumption rate, but few studies have connected endocrine disrupting compounds with this metabolic endpoint. In turn, metabolic rate has been shown to be closely linked with individual differences in behaviour. Triphenyl phosphate (TPHP), a chemical commonly used as a plasticizer and flame retardant, has been detected in wild birds and is identified as a potentially high-risk chemical. TPHP disrupts the central regulation and hormone synthesis pathways of the thyroid system in fish, which regulates growth and metabolism, but little is known about its effects in birds. Japanese quail (*Coturnix japonica*) chicks were exposed in ovo and orally for 6 d to safflower oil (control), 5 (level in wild bird eggs in Canada), 50, or 100 ng/g TPHP, or 100 ng/g diphenyl phosphate (DPHP), a major metabolite of TPHP. We measured growth (body weight and tarsus length), O2 consumption using an open-flow gas respirometry system, and assessed thyroid gland histology and circulating thyroid hormone concentrations, all endpoints related to the thyroid system. We observed a dose-dependent suppression of chick growth and O2 consumption. Understanding linkages between hormones and metabolism may help us to predict the population-level consequences of environmental exposure to endocrine disrupting contaminants in birds.

S6-10 GUINDRE-PARKER, S.*; RUBENSTEIN, D.R.; University of Guelph, Columbia University; *slg2154@columbia.edu*

Coping with environmental uncertainty using the avian glucocorticoid response

Glucocorticoid hormones are dynamic and flexible, and can promote appropriate behavioral responses following predictable perturbations in an animal's environment. However, climate change is expected to increase the frequency of unpredictable weather in many habitats, and little is understood about how organisms respond to unpredictable changes in their environments. We will explore how glucocorticoids may serve to cope with unpredictability in rainfall—a key driver of insect availability—by comparing the glucocorticoid profiles of superb starlings (*Lamprotornis superbus*) sampled across 9 populations in Kenya. Our intra-specific endocrine dataset allows us to disentangle the effects of environmental conditions from unpredictability in these conditions, because the populations we studied differ independently in total annual rainfall and the unpredictability of rainfall they experience. Additionally, we sampled each population under two types of conditions (i.e. regular year vs. El Niño year), which enables us to tease apart the effects of short-term weather from long-term environmental conditions on glucocorticoid profiles. We highlight the importance of intra-specific studies in evolutionary endocrinology research, as these allow us to better unravel the relationships between hormones and various environmental variables that otherwise co-vary on a global scale.

7-3 GUMM, JM*; TINGHITELLA, RM; GUMM, Jennif; Stephen F. Austin State University, University of Denver; *gummj@sfasu.edu*

Opsin expression in threespine sticklebacks that differ in male color and competition

Threespine sticklebacks (*Gasterosteus aculeatus*) are a classic example of sensory drive, which predicts covariation in sensory environments, visual systems, and signals that result in divergent mate preferences, and drive reproductive isolation. In the breeding season, male sticklebacks develop a bright red throat but in many western North American freshwater rivers and streams, the red throat has been lost and males instead have ‘black' or ‘melanic' body coloration. In contrast to the classic system, populations that differ in expression of the red throat in Washington differ dramatically in male competition, but not female preference. We utilize this system to evaluate if visual systems co-vary with signals involved in male competition. At least two molecular mechanisms can explain variation in visual sensitivity. Sequence differences in the opsin protein or differential expression of opsin genes can alter spectral sensitivity. In sticklebacks, there is little variation in spectral sensitivity or opsin sequences. However, several recent studies show that opsin expression can evolve very rapidly and is plastic, changing in response to environmental conditions on very small spatial and temporal scales. We evaluated opsin expression patterns in 1 red population and in 3 black populations that differ in age of colonization from 16,000 to millions of years, and likely represent independent losses of red coloration. Using qPCR methods assessing relative levels of gene expression of opsins, we test 1) if opsin expression differs between populations that differ in male breeding color and 2) if opsin expression varies in parallel across populations representing independent changes in color with different times since colonization. Our results highlight the role of visual systems in mediating male competition in the stickleback system.

17-3 GUNDERSON, AR*; ABEGAZ, M; CEJA, A; LAM, E; SOUTHER, J; BOYER, K; KING, E; YOU MAK, K; TSUKIMURA, B; STILLMAN, JH; UC Berkeley, San Francisco State, Cal State Fresno; *argunderson3@gmail.com*

Fine-scale spatial and temporal temperature variability and it's energetic consequences within intertidal boulder habitat

Intertidal zones represent some of the most thermally dynamic habitats on earth, and are a classic system for understanding the ecological consequences of fine-scale temperature variability. However, most intertidal studies focus on exposed rock surfaces and the organisms that specialize on them, such as mussels and snails. We report fine-scale temperature data for temperatures under rocks on a boulder shore on the coast of Northern California. Data loggers were placed under 24 rocks from the mid- to the high-intertidal zone on a single shore, yielding over 420,000 temperature records across 18 months. Energetic consequences of thermal variability were predicted for the porcelain crab *Petrolisthes cinctipes*, a common boulder shore native, using laboratory measures of temperature-dependent metabolism in air and water. High intertidal rocks consistently had higher daily maximum and lower daily minimum temperatures than mid intertidal rocks due to longer emersion during warm daytime hours and cold nighttime hours, respectively. Somewhat surprisingly, metabolic expenditure by *P. cinctipes* was predicted to be very similar between the high and mid zones. This is primarily due to the fact that transient high temperatures experienced during daytime emersion in the high intertidal are offset by cold nighttime temperatures and depression of metabolism in air. Our results demonstrate that the energetic consequences of fine-scale temperature variability in the intertidal can be complicated by unintuitive temperature dynamics and the complex metabolic physiology of intertidal organisms.

108-5 GUNN, TR*; BEDORE, CB; Georgia Southern University ; *tg03328@georgiasouthern.edu*

Environmental and Physiological Regulation of Stingray Camouflage

Many reef fishes exhibit dynamic coloration and body patterns that can change under nervous or hormonal control. Lowe et al (1996) showed that hammerheads in high UV environments have higher skin melanin concentrations, which likely functions as a protective mechanism against UV damage. However, several species of benthic sharks and rays likely alter melanin concentrations in the skin to provide background matching for camouflage. The yellow stingray (*Urobatis jamaicensis*) and the smooth butterfly ray (*Gymnura micrura*) are benthically-oriented elasmobranchs with elaborate spot patterns that provide effective camouflage within their habitats. This patterning, when coupled with the ability to alter melanin concentrations in response to background color, could increase background matching effectiveness in these species. Both species have been anecdotally noted to lighten or darken skin color. However, despite the wide array of studies conducted on color change for enhanced background-matching capabilities in bony fish, this ability remains understudied among elasmobranchs. To investigate this, we housed rays in either black or white tanks for one week and photographed the rays daily. Stingrays in black tanks significantly darkened skin color over the seven-day period whereas rays in white tanks significantly lightened their skin color during the same period. On the last day, blood and tissue samples were taken in order to further examine the underlying physiological mechanisms that control color change through quantification of key hormones and melanin concentrations.

45-2 GUOYNES, CD*; MARLER, CA; GUOYNES, Caleig; UW Madison; *guoynes@wisc.edu*

Parental communication with newborn pups and the effects of oxytocin in the California mouse (Peromyscus californicus)

The neuropeptide hormone oxytocin (OT) influences social bonding and parental care in both human and animal models. We examined the acute effects of intranasal OT (0.8 IU/kg) on parental behavior in male and female California mice (Peromyscus californicus), a strictly monogamous, biparental rodent. California mice have relatively small litters and offspring stay with their parents longer compared to other rodent species. Both mothers and fathers show high levels of licking and grooming. Regarding ultrasonic vocalizations in parent-offspring interactions (USVs), the primary focus of research has been on whether pup calls elicit parental care. Here, we focus on the parents' USVs toward the pups and how OT alters USVs during a pup retrieval experiment. California mice produce five distinct ultrasonic vocalizations: barks, long-distance sustained vocalizations (SV), simple sweeps (SS), complex sweeps (CS), and sweep phrases (SP). Mothers and fathers were tested individually, and maintained in separate rooms during the experiments to ensure that each parent was only communicating with the offspring. Preliminary data analysis shows that mothers produce sweep USVs only when they are interacting with pups; sweep frequency increases during licking and grooming and disappears when mothers and pups are separated. Additionally, we found that fathers produce sweep-phrases toward pups during retrievals. Comparisons between OT and saline groups including number, duration and type of USV calls, and pup responses to different types of parental USV calls will be reported. This finding identifies a novel, affiliative function for sweep calls.

111-2 HADFIELD, MG*; FRECKELTON, ML; NEDVED, BT; University of Hawaii at Manoa; *hadfield@hawaii.edu*

Metamorphosing larvae of Hydroides elegans (Polychaeta): the first 30 minutes on the bottom

The serpulid polychaete *Hydroides elegans* is an excellent model organism for studies of larval settlement and metamorphosis in response to bacterial biofilms. However, despite 25 years of study, aspects of attachment and morphogenesis remain confused. In current research, detailed observations of larvae were made from the moment of contact with: a natural biofilm; a monospecific biofilm of the bacterial species *Pseudoalteromonas luteoviolacea*; and an active extract of the same bacterium. Prior studies have shown that these larvae do not detect a natural biofilm by the presence of dissolved substances, and must contact a biofilm before metamorphosis is initiated. When observed under controlled conditions, after contact with a natural biofilm or a biofilm of *P. luteoviolacea* alone, larvae explore the biofilm for up to 10 min, stop moving, and secrete a primary organic tube, which anchors them longitudinally on the substratum. Only minutes later, compound cilia of the prototroch are resorbed, and metatrochal cilia are shed. Then, still within the first 25 min. of biofilm contact, the double row of ciliated cells that lines the food groove is shed in small clusters, most of which are eaten by the larva. The result of all this loss is the creation of a deep groove separating the trunk, just anterior to the collar, from the head region. Interestingly, when larvae are treated with a cell-free extract from *P. luteoviolacea* the natural order of metamorphic events is disturbed, so that trochal cilia disappear prior to primary tube formation. Clearly, were this sequence to occur in the real world, the larvae would lose their ability to move about without the anchoring stability of the primary tube, and be blown away by turbulent water flow.

141-5 HAGAN, R. H.; SZUTER , E. M.; ROSSELOT, A. E.; HOLMES , C. J.; SILER , S. C.; ROSENDALE , A. J.; JENNINGS, E. C.; XIAO, Y.; WATANABE, M.; ROMICK-ROSENDALE, L. E.; RASGON, J. L.; BENOIT, J. B.*; University of Cincinnati , Cincinnati Children's Hospital Medical Center, Pennsylvania State University; *joshua.benoit@uc.edu*

Dehydration-Induced Phenotypic Shifts in Mosquitoes Increase Blood Feeding

Bouts of dehydration are common for mosquitoes, but previous studies on mosquito dehydration have examined very specific responses and have not studied multiple facets underlying mosquito biology during dehydration. Here, we utilized an integrative approach to assess the response of the northern house mosquito, *Culex pipiens*, to periods of dehydration. We show that dry periods increased mosquito blood feeding, which was due to increased activity and a higher tendency to land on a host. Mosquitoes exposed to dry conditions with access to water remain hydrated and failed to display behavioral changes. Combined RNA-seq and metabolome analyses of dehydrated mosquitoes revealed that carbohydrate metabolism is altered, specifically the breakdown of trehalose to glucose. Suppression of trehalose breakdown by RNA interference of *trehalase* reduced phenotypes associated with lower hydration levels. Lastly, mesocosm studies for *C. pipiens* revealed that dehydrated mosquitoes were more likely to blood feed, even when sugar and water sources are available. These results suggest that dehydration may prompt mosquitoes to utilize blood feeding as a mechanism to obtain water. Dehydration-induced increases in blood feeding are therefore likely to occur at any time and will intensify during periods when availability of water is low.

P1-12 HAGEY, T*; WARWICK, A; MEAD, L; Michigan State University; *hageyt@egr.msu.edu*

A Classroom Activity Simulating Population-Level Evolution by Hand

We have developed a scalable classroom activity that illustrates how evolution occurs at the population level, specifically the inheritance and variation of a trait with and without natural selection. The Next Generation Science Standards cite inheritance and variation of traits, natural selection, and evolution as disciplinary core ideas (NGSS LS3/LS4). Our activity was designed to align with these goals. The simplest version of our activity, introduces students to drift, selection and fitness, and tree thinking. Advanced versions of our activity build on our simpler versions, incorporating higher-level concepts. Our activity considers bird color, but the patterns illustrated are general to all of evolution. Students model the evolution of bird color in a population through time. Using a board-game type spinner, students assign phenotypes (plumage color) and differential reproduction to individual, asexual, birds across a population, over successive discrete generations. At the completion of the activity, students have created a pedigree of individuals, showing how plumage color has changed over time and its relationship to surviving clades. Students' results illustrate population-level processes that generate morphological diversity.

125-6 HAGUE, MTJ*; BRODIE JR., ED; BRODIE III, ED; University of Virginia, Utah State University; *mh6nf@virginia.edu*

Trade-off between predatory and locomotor ability in a geographic mosaic of coevolution with toxic prey

Evolutionary trade-offs are predicted to arise when a locally adapted allele exhibits antagonistic effects in a foreign environment. Genetic polymorphism will then be maintained among populations that experience divergent patterns of selection across a heterogeneous landscape. We tested for trade-offs at a polymorphic locus of large-effect that determines toxin resistance in populations of the common garter snake (*Thamnophis sirtalis*). Two separate lineages of *T. sirtalis* in western North America independently evolved changes to the skeletal muscle sodium channel (Na_V1.4) that confer resistance to tetrodotoxin (TTX) in their prey, Pacific newts (*Taricha* spp.). In California populations, we found that homozygous snakes with a highly resistant allele of the Na_V1.4 channel had a slower average crawl speed than individuals with the ancestral, TTX-sensitive channel. Previous molecular work indicates the same TTX-resistant mutations have pleiotropic effects on a range of important biophysical properties of the Na_V1.4 channel. A negative relationship between TTX resistance and locomotor performance suggests trade-offs could maintain polymorphism in the Na_V1.4 channel of *T. sirtalis* across the geographic mosaic of variably toxic newt populations.

121-6 HALL, JM*; WARNER, DA; Auburn University; *jmh0131@auburn.edu*

Embryological development and global change: how do reptile embryos respond to thermal stress in urban environments?

Two components of global change, climate change and urbanization, both contribute to increased ambient temperatures that may induce heat stress or mortality in animals. Each phenomenon independently results in both increased mean temperatures and increased maximum day-time temperatures; however, there is also the potential for these components to act synergistically: extreme temperatures due to the urban heat island effect are likely to be exacerbated as the earth's surface warms due to climate change. Many animals can respond to harmful temperatures behaviorally, by altering their periods of activity or shifting their habitat use. Such behavioral compensation, however, is unavailable to embryos of ectotherms which typically develop inside eggs in the ground and receive little or no parental care. Thus, this early life stage is expected to be more vulnerable to harmful temperatures caused by aspects of global change, and yet, the effects of ecologically relevant thermal stress on these embryos has received little attention. We sought to understand the consequences of such extreme temperatures on embryological development by utilizing two species of lizard (*Anolis sagrei* and *Anolis cristatellus*) that commonly inhabit urban areas. We measured ground temperatures in an urban landscape where lizards nest and modeled daily thermal fluctuations that included brief periods of extremely high temperatures. We then subjected eggs of both species to various magnitudes and frequencies of these thermal fluctuations at multiple stages of embryological development. We report the effects on survival, physiology, morphology, and performance of these ecologically relevant thermal regimes and highlight the potential for extreme incubation temperatures to differentially impact species.

P3-23 HALL, BE*; BEDORE, CN; Georgia Southern University; *Bh06426@georgiasouthern.edu*

Comparative visual morphology of sharks

Eye size and shape are important for determining the significance of vision to both individuals and to species whereby large eyes have greater resolution and sensitivity. Within an individual, eye growth is metabolically costly, suggesting that large eyes play a larger role in the ecology of an animal. Vision can also provide insight into prey selection, predator and mate detection capabilities, and habitat utilization. For example, elasmobranchs demonstrate a variety of pupil morphologies including vertical and horizontal slits, pinholes, and crescents. Pupil shape is correlated to an organism's environmental light level and time of day it is most active. Although some studies have investigated eye and pupil shape in select elasmobranch species, less is known regarding eye and pupil shape on a broader scale. Eye size, eye shape, and pupil shape of seven coastal elasmobranchs from the southeastern United States were quantified using photographic analyses: Atlantic sharpnose (*Rhizoprionodon terraenovae*), blacktip (*Carcharhinus limbatus*), finetooth (*Carcharhinus isodon*), dusky (*Carcharhinus obscurus*), sandbar (*Carcharhinus plumbeus*), scalloped hammerhead (*Sphyrna lewini*), and bonnethead (*Sphyrna tiburo*). All species had round eyes with vertical slit pupils, with the exception of the hammerheads (*Sphyrna* spp.), which possessed slightly oblong eyes with horizontal pupils. As benthic feeders, a horizontal pupil reflects their plane of vision while foraging. Scalloped hammerheads had the largest eye size relative to their body length. Because visual sensitivity positively scales with eye size, scaling should also be considered in future analyses.

P3-204 HALL, MR*; BERG, O; MÜLLER, UK; CSU Fresno; *maxwellhall@mail.fresnostate.edu*

Trap activity and efficiency in Utricularia vulgaris

Utricularia vulgaris, the common bladderwort, uses an active-mechanism suction trap to capture prey. This trap comprises a hollow bladder with a door and is set through continuously pumping water from the bladder to maintain a negative pressure. The trap is sprung when hairs at the mouth of the bladder encounter prey, releasing a door at the mouth and sucking in the prey. The traps appear to misfire on a frequent basis, forcing them to reset continually through pumping out water. This energetic cost of setting and resetting varies with the size of the traps. Due to this size effect on cost we hypothesize that there should be an increased success or payoff for larger traps. In addition to the energetic cost, the resource cost associated with trap formation also scales with size. To determine the activity and the volumes of water pumped by each trap we used UV fluorescent dye to measure the activity of *U. vulgaris* over 48 hours. Dye sucked into traps can't escape and the dye concentration increases with each trap firing, allowing us to measure volume intake. Image analysis of full plants after the dye treatment allowed measurement of trapping activity and feeding success of the individual traps. We found that the youngest traps and recently matured traps trigger frequently yet are very unlikely to capture prey. Mature traps rarely trigger, but are likely to capture prey. The elevated firing rate of young traps has high energetic costs. Explanations for this possibly maladaptive trait could be either that the trap door is initially unable to withstand the bladder pressures, or that the bladder walls are initially unable to maintain subcritical pressures.

P2-93 HALL, HR*; KAHRL, AF; JOHNSON, MA; Trinity University, Stockholm University; *hhall@trinity.edu*

The Evolution of Testis and Sperm Morphology in Anolis Lizards

The major function of the testes is sperm production, or spermatogenesis. Across species, there are dramatic differences in sperm morphology, and this variation results (at least in part) from differences in the duration and patterns of cell division during spermatogenesis. Further, testis architecture may evolve in correlation with sperm morphology, as for example, sperm tail length is correlated with the evolution of thicker epithelia of the seminiferous tubules in birds. In this study, we examined relationships between testis architecture and sperm morphology in a group of 28 species of *Anolis* lizards from the Dominican Republic, Puerto Rico, Bahamas, and the United States. Using cryosectioned testis tissues, we measured the cross-sectional area of each testis, the seminiferous tubules within the testis, and the lumina of the tubules. We also measured sperm head, midpiece, and tail lengths for each species. Preliminary analyses in a subset of 16 species suggest that, after controlling for body size, species with larger testes produce sperm with longer heads, and seminiferous tubules with larger lumina and thicker epithelia produce sperm with longer tails. Our current work examines the cell-type distribution and density in the testes of each species, to determine patterns of tissue efficiency in sperm production. This study will allow us to better understand the relationship between the evolution of testis morphology and sperm production strategies across a species group.

85-2 HALL, JK; MCGOWAN, CP; LIN, DC*; Washington State University, University of Idaho; *davidlin@wsu.edu*

Comparison between hopping on solid and sand substrates

Different surface substrates change the ability of an animal to generate the ground contact forces that propel locomotion. Thus, the overall behavior of the locomotor pattern, namely the coordination of the movement, may change drastically. However, specific animals may be well adapted to locomotion on different substrates given that they experience those substrates in their natural environment. To address this question, we compared the kinematics of the kangaroo rat (Dipodomys deserti) while hopping either on a solid surface or on sand. High speed video was used to record the kinematics of 6 animals while hopping on a specially designed rotatory treadmill upon which we were able to place sand or have just the bare wooden surface. Visual markers on the midfoot, ankle, knee, hip, and pelvis were digitized and joint angles calculated. We found that for comparable speeds, the contact time with the ground was longer and was a greater percentage of the hop cycle on sand versus the solid surface. This result was expected given the physics of the sand extended the time to decelerate and accelerate the foot. The velocity of the pelvis, which is close to the center of mass of the animal, were remarkably similar, showing that the overall hopping movements on each surface were similar. The distinctive difference between hopping on the two surfaces was the posture of the animal, in that the average length of hindlimb (measured as the distance between the midfoot and hip) was longer for hopping on the solid surface. This result showed that a more crouched posture was adopted by the animal for hopping on the sand to compensate for the different biomechanical demands of the sand surface.

P1-134 HALLAS, JM*; FELDMAN, CR; BRODIE III, ED; PFRENDER, ME; BRODIE JR, ED; PARCHMAN, TL; Univ. of Nevada, Reno, Univ. of Virginia, Univ. of Notre Dame, Utah State Univ.; *jhallas@nevada.unr.edu*

Adaptive Variation in the Sierra Garter Snake (Thamnophis couchii): Influence of Biogeography and Genetic Structure on Patterns of TTX-Resistance

Most species consist of multiple genetically differentiated populations that undoubtedly experience different community contexts and forms of natural selection. This allows the interface of gene flow and selection to continuously shape the spatial patterning of population structure and adaptive variation across geographic space. Despite the importance of a population genetic perspective for understanding the evolutionary consequences of the geographic mosaic of coevolution, few studies have thoroughly characterized both the form and outcome of natural selection on population genetic structure across geographic mosaics of coevolution. Here, we quantify the phenotypic variation and population structure in the Sierra garter snake (*Thamnophis couchii*) using 26,121 SNPs to understand the geographic scale at which gene flow might be reduced among populations, and thus, allow for independent local adaptation in response to variation in the tetrodotoxin (TTX) defense of its Pacific newt prey (*Taricha*). We documented phenotypic variation in across the range, with snakes from the southern part of the distribution having much higher resistance. Phylogenetic analyses indicate that greater resistance evolved as *Th. couchii* colonized southern regions of its range. We documented surprisingly fine scale population genetic differentiation at the level of neighboring watersheds. Our results suggest that the geographic scale of the outcome of coevolutionary interactions is likely to be narrow, which could facilitate the evolution of adaptive variation across fine spatial scales.

84-7 HALSEY, MK*; RAY, DA; BRADLEY, RD; STEVENS, RD; Texas Tech University; *michaela.halsey@ttu.edu*

Present-Day Species Distributions of Pocket Gophers in Texas

Technological advances, such as the development of geographic information systems, have provided the study of biogeography with unprecedented levels of data manipulation and interpretation of geographic and biological data. In conservation, with the goal of ensuring enough suitable habitat and connectivity for both gene flow and dispersal across fragmented habitat, biogeographical understanding of species can be illuminating. However, management considerations for certain species can be ill-informed if information on current species distributions is incomplete. This is especially relevant in heterogeneous landscapes with high species diversity. Texas, the second largest state in the U.S. that spans 10 distinct ecoregions, has some of the highest pocket gopher diversity nationwide. With 11 species and nearly 30 described subspecies, little is known about the present-day distributions of pocket gophers within the state. Moreover, the hypothesis that increasing aridity facilitates the displacement of *Thomomys bottae* by *Cratogeomys castanops* in west Texas has yet to be addressed by an ecological modeling approach. To address the need for improved distribution maps to better inform conservation management, three genera of pocket gophers were collected across the state of Texas. Museum records from each genus were incorporated to provide historical context. Here, using a maximum entropy algorithm, we compare past and present-day ecological niche models for selected species using fine-scale soil, vegetation and climate data, which includes aridity measures. These models will provide not only a clearer outlook on the management needs of pocket gophers in Texas, but can offer new insights to the physiological requirements of these fossorial rodents.

P1-209 HAMAR, JC*; KÜLTZ, D; Univ. of California, Davis; *jchamar@ucdavis.edu*

Interrogation of Tilapia Osmoregulation using CRISPR in a Cell Culture Model

Osmotic stress is one of the primary challenges faced by aquatic animals and their capacity to osmoregulate in response will dictate its survivability within a given set of conditions. The Mozambique Tilapia (*Oreochromis mossambicus*) is an ideal model organism for studying the physiology behind this response due its extreme ability to adapt to this type of stress. A cell line was derived from *O. mossambicus* brain tissue (OmB) that retains much of the osmotically induced proteome phenotypes observed in adult tissues of this animal. Cell cultures can facilitate these studies by providing a means to further isolate and examine individual components, such as proteins and the genes that encode them, of the mechanisms behind adaption to osmotic challenges. Valuable functional information can be obtained through observation of specific phenotypes caused by genetic manipulations of these components. CRISPR/Cas9 gene editing systems have proven to be a potent means to induce targeted genetic manipulations in cell culture from a variety of vertebrate taxa including fish. A "proof of principle" assay was performed to demonstrate function of the CRISPR/Cas9 system in the OmB cell line by targeting and knocking out transgenic expression of EGFP. Following treatment with expression plasmids encoding the required EGFP targeted CRISPR/Cas9 components, examination by fluorescence microscopy showed a marked reduction of cells with detectable EGFP fluorescence relative to controls providing visual evidence of function of the system in these cells. Current work involves adapting a plasmid based system to implement CRISPR/Cas9 targeting of relevant previously identified genes to help decipher cellular osmotic stress response mechanisms using the OmB cell line model. Funded by NSF grant IOS-1355098 and BARD grant IS-4800-15R.

114-7 HAMDA, NT*; HEIN, A; MARTIN, B; DANNER, E; NOAA Southwest Fisheries Science Center; Univ. of California, Santa Cruz, NOAA Southwest Fisheries Science Center; *natnael.hamda@noaa.gov*

Quantitative Classification of Animal Behaviours from Time-series Tracking Data: Machine Learning Techniques

Animals perform a variety of behaviors as they go about their daily lives. Biologists often think of these behaviors as being distinct from one another and the set of distinct behaviors an animal can execute is often referred to as that animal's "behavioral repertoire." Defining the behavioral repertoire of a given individual or species is a challenging and often subjective task. Here, we implement new unsupervised machine learning techniques to discover the behavioral repertoire of freely moving animals directly from tracking data. We further apply a dynamical machine learning approach to determine when animals transition from one distinct behavior to another using time series data. To demonstrate these methods, we apply them to data from a study of acoustically tagged salmon and salmon predators conducted in the Sacramento-San Joaquin River Delta, California. We first applied unsupervised machine learning for the quantitative classification of salmon and predator movement behavior from acoustic tagging data. This allows us not only to map the behavioral repertoires of the salmon and their predators, but also to define a transition probability of behavioral patterns between two observed time points. In the second step, we applied a statistical machine learning technique to identify predator attacks and predation events using a change-point detection algorithm. The change-point detection allows us to qualitatively determine if the behavior of the time series of the salmon changes and to identify the time point when this change occurs.

P1-253 HAMZAH, LH*; QUINN, DB; LENTINK, D; Stanford University, University of Virginia; *latifah@stanford.edu*

Passive Yaw Stability of Flapping Wings

The stability and dynamics of flapping flight is still not fully understood. In particular, the forces that contribute to yaw dynamics, especially the extent to which stable flapping flight in yaw is achieved via passive versus active mechanisms, remain unclear. A current hypothesis for a physical yaw dynamics model contains three terms that are derived from flapping counter torque and a restoring torque that reorients flappers into the relative oncoming wind. This passive reorienting torque has no precedent of which the authors are aware. Here we study this torque via wind tunnel experiments on an ornithopter which, after a perturbation in the yaw direction, successfully reorients itself into the wind. In comparing these results to experiments conducted on similar fixed wing aircraft, we show that flapping indeed contributes to passive yaw stability. The findings help interpret the yaw dynamics of birds and may also apply to insects and bats and can help improve the yaw stability of robots with flapping wings.

61-4 HAN, SI*; ASTLEY, HC; BLACKLEDGE, TA; University of Akron; *sih12@zips.uakron.edu*
Slingshot Motion of the Hyptiotes Spider Created by External Power Amplification in the Web
Power amplification through elastic body structures allows animals to generate fast motion beyond the capacity of muscle contraction alone, such as the mantis shrimp's strike and the flea's jump. Although some animals like orangutans use external structures to facilitate motion, power amplification through the use of tools or other external structures has never been reported in a non-human organism. Here we demonstrate the first example of power amplification through a constructed external device: the web of the triangle spider, *Hyptiotes*. The spider stores energy in its web by pulling it taut, similar to drawing back a slingshot or bow string, then releases it for a rapid movement that propels the spider forward. This example of external power amplification has implications for both prey capture and predator escape using an easily renewable and repairable structure that serves as both refuge and tool.

49-7 HAN, Y*; LI, C; Johns Hopkins University; *yhan33@jhu.edu*
Cockroach and Robot Locomotion Reveals the Need to Integrate Sensory Feedback with Body Mechanics to Traverse Complex 3-D Terrains
Analogous to how aerodynamic shapes and control surfaces help modulate forces during flight, recent studies demonstrated that body shape plays an important role in terrestrial locomotion in complex 3-D terrains. When encountering pillar obstacles, the discoid cockroach with an elliptical body shape often turned away from pillars (92 ± 4%) and traversed (81 ± 6%). By contrast, with a cuboidal body shape, the animal often turned towards and pitched up against pillars (86 ± 5%), but often eventually traversed (41 ± 8%). Here, to begin to understand whether passive body-terrain interaction is sufficient for traversing complex 3-D terrains or traversal requires sensory feedback, we tested a legged robot with no sensing capability and compared its locomotion with that of the animal. With an elliptical body, the feedforward robot almost always turned away from the pillar (98 ± 2%) and traversed. With a cuboidal body, although the feedforward robot usually turned towards the pillar (96 ± 2%), unlike the animal which often traversed, the robot almost never traversed (2 ± 1%), but was instead trapped pitching up against the pillar and eventually flipped over (98 ± 2%). This distinct difference suggested that, although the passive body-terrain interaction affected movement during the initial phase of obstacle negotiation, the animal likely used active sensory feedback to overcome it in order to traverse. To begin to study this, we impaired sensory feedback of the animal by cutting off its antennae. We found that the animal without antennae was more likely to flip over (43 ± 27%) than with antennae (6 ± 4%; $P < 0.0001$, ANOVA), and thus traversed less often. Our study provides inspiration for robot to integrate sensory feedback with terradynamic shapes to better traverse complex 3-D terrains.

P1-129 HANCOCK, ZB; Texas A&M University, College Station; *zhancock@bio.tamu.edu*
Two New Species of Sand-Burrowing Amphipods of the Genus Haustorius (Haustoriidae) from the Northwestern Gulf of Mexico
Many undescribed species of the genus *Haustorius* Muller 1775 have long been known to exist in the Gulf of Mexico. These sand-burrowing amphipods are abundant intertidal members of fine sand beaches. Two new species are here described, *Haustorius galvezi* **sp. nov.** and *Haustorius allardi* **sp. nov**. The range of *H. jayneae* is extended to Carrabelle Beach, FL. A review of the genera *Haustorius* and *Lepidactylus* is included, as well as notes on their ecology and biogeography. Additionally, a full key to all known Haustoriidae of the Gulf of Mexico is presented.

25-5 HANKEN, J*; TURNEY, SG; FORD, LS; Harvard University; *hanken@oeb.harvard.edu*
Unlocking the Vault: Mass Digitization and Imaging of Historical Slide Collections for Use in Comparative Biology
Natural history museums hold vast collections of glass microscope slides amassed from a variety of sources over the last 100 or more years. These slides were prepared in association with botanical and zoological studies, which ranged from comparative embryology, to wood anatomy, to plant-insect mutualisms. While such collections represent a unique and irreplaceable resource for studies of integrative and comparative biology, most are fragile or otherwise difficult to access and work with. Hence, they are largely ignored by contemporary researchers. We have developed a cost-effective, high-throughput and semi-automated workflow for digitally scanning and displaying slides of many different sizes characteristic of the collections of the Harvard Museum of Comparative Zoology and the Harvard University Herbaria, which is applicable to like collections at other institutions. The resulting high-resolution digital images, each depicting the contents of an entire slide, may be accessed via a customized web application that allows a variety of kinds of image analysis and data capture. Ready access to these historically and scientifically rich data sources will enable fruitful and timely collaborations between natural history museums and other branches of biology, such as neuroscience, physiology, developmental biology, functional morphology and ecology, and complements the growing number of digital-image repositories available via the Internet.

P3-63 HANSEN, BK*; MBA MEDIE, F; SHARMA-KUINKEL, BK; FOWLER, VG; RADER, Jonath; Duke Univ.; *brenda.hansen@duke.edu*

Host Genetics Contribute to Susceptibility to Infection, and Outcome of Disease in the Crif1 Knockout Mouse

Staphylococcus aureus is a common cause of hospital-acquired illness worldwide, with ~14 million US patients seeking treatment for infections each year. While the outcomes of *S. aureus* exposure can range from asymptomatic colonization to fatal infection, the factors influencing the severity of infection are not fully understood. Host genetics can play a significant role in disease susceptibility, and identifying genes relevant to susceptibility to specific pathogens, including *S. aureus*, may be important for predicting which populations are more vulnerable to life-threatening infection. Previous work in our lab identified three chromosomes (8, 11, and 18) associated with susceptibility to *S. aureus* infection in A/J mice, along with several candidate genes with human orthologues that may be particularly important. Our current work focuses on the *Crif1* gene, located on chromosome 8. Downregulation of *Crif1* is associated with apoptosis, a key player in the control of immune response. We used the primary murine macrophage model to compare phagocytosis, replication, and cytokine production in bone marrow-derived macrophages (BMDM) isolated from *Crif1* knockout mice and C57BL/6 (B6), an established wild type control for *S. aureus* resistance. Preliminary results show no difference in phagocytosis of *S. aureus* by BMDM as determined by colony forming units. The intracellular *S. aureus* replication in BMDM was comparable in both mouse lines. Finally, using the Luminex-bead based assay, we found that the cytokines IL-6, IL-12, MCP-1, and MIP-1α were higher in *Crif1* BMDM compared to B6. Our preliminary data suggests that *Crif1* plays an important role in host immune response, and may lead to increased susceptibility to *S. aureus* infection when absent.

57-5 HANSON, H.E.*; KILVITIS, H.J.; SCHREY, A.W.; MARTIN, L.B.; University of South Florida, Armstrong State University; *haleyhanson@mail.usf.edu*

Epigenetic Potential in Native and Introduced Populations of House Sparrows

Epigenetic potential, or the capacity for epigenetically-mediated phenotypic plasticity, may play an important role during range expansions. As range-expanding populations face comparatively novel ecological challenges and can be genetically constrained due to bottlenecks and/or founder effects, they might often rely on phenotypic plasticity via epigenetic mechanisms to rapidly cope with these challenges. Here, we asked whether one proxy for epigenetic potential (i.e. the abundance and/or position of CpG sites within gene promoters) varied among three native and three introduced populations of house sparrows (*Passer domesticus*). DNA methylation primarily occurs at CpG sites and we recently discovered that methylation at one CpG site within the putative promoter region of a microbial surveillance gene (Toll-like receptor 4, TLR-4) was a strong predictor of TLR-4 expression in house sparrows. We characterized i) total CpG sites, ii) SNPs in CpG sites, and iii) overall SNP variation within the putative promoter region of TLR-4. We hypothesize that SNP variants represent genetic assimilation of initially pure (environmental) epigenetic effects, particularly when they occur within or near CpG sites. We found more unmodified CpGs (those lacking SNPs) and fewer SNPs overall in birds from introduced populations. Moreover, we found greater variation in the number of SNPs among CpG sites in native populations, suggesting selection against some SNPs in introduced populations and/or assimilation of previously epigenetic effects in native ones. These results support a role for epigenetic potential in the range expansions of this species, and have instigated a more intensive study using epi- and ddRADseq.

57-4 HANTAK, MM*; PAGE, RB; ANTHONY, CD; KUCHTA, SR; Ohio University , Texas A&M University, John Carroll University; *mh433113@ohio.edu*

Evaluation of the Genetic Structure of a Color Polymorphic Salamander, Plethodon cinereus

Color polymorphism is the presence of two or more distinct, genetically determined color morphs within a single interbreeding population. An underexplored question in color polymorphic species pertains to how the phenotypes are maintained among populations. Little work has been done to examine geographic patterns in polymorphisms, with most studies focusing on a single population. Mechanisms that may maintain polymorphisms include negative frequency dependent selection, spatiotemporal variation in selection, and gene flow among populations. Investigating these mechanisms in multiple populations provides insight into the processes underlying the maintenance of genetic variation within and among populations. The Eastern Red-backed Salamander, *Plethodon cinereus*, is widespread throughout northeastern North America, and has two common color morphs. Previous studies have suggested that the two color morphs of *P. cinereus* differ in many elements of their biology, including physiology, territoriality, and mating interactions. However, most studies focus on a single biological feature in a single population, so little is known about diversifying selection, co-adapted gene complexes, or multivariate niche differentiation. In addition, the evolutionary processes that maintain the polymorphism in populations are not understood. Using microsatellite loci, this study aims to determine whether geographic distance or phenotype is more heavily correlated with genotypic divergence. Overall, this study provides critical information on the role of gene flow and natural selection in the evolution and maintenance of this color polymorphism, and links patterns of genetic differentiation with an understanding of the ecology of morph differences in *P. cinereus*.

22-2 HARDY, AR*; HALE, ME; Univ. of Chicago; *arhardy7@uchicago.edu*

The role of substrate contact on pectoral fin sensory regionalization

Bottom dwelling fishes interact with the substrate using their fins and have the ability to sense touch using mechanosensory afferents. Characterization of response properties as well as targeted immunostaining has revealed distinct populations of mechanoreceptors in the fin. Here we investigate 1) how the pectoral fins of the round goby (*Neogobius melanostomus*), a bottom dwelling species, are positioned and move during substrate associated behaviors, 2) whether fin functional regionalization relates to sensory morphology, and 3) how afferents encode relevant information about substrate contact. At rest as well as during movement, a degree of fin ray bending and lateral shear movement across contacted surfaces occurs. Substrate contact is primarily localized to the medial aspect of the ventral-most fin rays at their distal tips. Immunolabeling reveals regionalization of mechanoreceptors, as Merkel cell density decreases sharply in the distal tips. Using linear brush stimulations, we show afferents at the distal tips where substrate contact is highest exhibit small receptive fields (~2-4mm) and little variability in response onset to a repeated stimulus. As stimulus velocity increased, the mean firing rate associated with these afferents' receptive field increased suggestive of a possible velocity encoding mechanism. In response to textured patterns of varying coarseness, a subset of the mechanoreceptor population spatially encode coarse surface features with high precision. The response of these afferents to a given texture is speed invariant and appear better suited to encoding coarser textures. The data suggest that much like the tetrapod somatosensory system, fins exhibit sensory and functional regionalization that facilitate the encoding of substrate features such as motion velocity and substrate roughness.

P3-211 HARIDY, Y; Univ. of Toronto, Mississauga ; *yara.haridy@mail.utoronto.ca*
Dental adaptations in monophyodont squamates; a histological study of the agamid Pogona vitticeps
Most extant and extinct squamates exhibit continuous tooth replacement, known as polyphyodonty, however there is a subset of squamates that has lost the ability and are now monophyodont (one tooth generation). The continuous replacement of teeth circumvents the need for wear adaptation, yet when the replacement mechanism is lost, dental wear becomes a factor. Modern chamaeleonid and agamid squamates, whom are monophyodont, exhibit adaptations to prolong the life of their dentition. Such adaptations include having mineralized tissues that infill the pulp cavity of teeth, which allows for the teeth to be worn away without the possibility of exposing the pulp cavity. In this study we present histological data of the agamid *Pogona vitticeps* showing that although these squamates lack tooth replacement, the mature individuals sampled do not infill their pulp cavities with any mineralized tissue, like that reported in other agamids. Pogona vitticeps seems to be depositing secondary dentine at the apex of the pulp cavity root-wards, essentially closing off the pulp cavity as the teeth are worn away. This gradual infilling of the pulp cavity is best seen through ontogeny. The juvenile specimens sampled have open pulp cavities and minimal wear, whilst the adults exhibit extensive wear and increased dentine thickness within the pulp cavity. This study shows that although several related families of squamates have lost the ability to replace their teeth, the adaptations differ between families. It is possible that the adaptations to compensate for this lack of replacement arose independently in chameleons and agamids.

59-5 HARO, D*; BURKE, RL; PAULY, GB; LIWANAG, HEM; California Polytechnic State University, Hofstra University, Natural History Museum of Los Angeles County; *daharo@calpoly.edu*
Reversible plasticity of whole body physiological parameters in an invasive lizard Podarcis siculus
Ectotherms require external heat from their environment to maintain their bodies in optimal temperature ranges. During winter, many terrestrial ectotherms respond physiologically by shifting their temperature tolerance ranges and increasing cold resistance. Most studies investigating plasticity of physiological variables look for the presence and direction of change, but very few investigate the rate of change. To examine the rate of cold responses, we simulated winter conditions for two non-native populations of the Italian Wall Lizard *Podarcis siculus*. In accordance with the climatic variability hypothesis, we predicted that animals from the more variable environment (Hempstead, New York) would have faster rates of acclimation to a cold environment compared to animals from a relatively stable environment (San Pedro, California). Animals were housed at 29°C for a year before beginning a cold acclimation treatment at 13°C. Whole body physiological variables (standard metabolic rate, evaporative water loss, thermal preference, and thermal tolerance) were measured prior to the acclimation treatment. Histological variables (serum osmolality, hematocrit, and hemoglobin concentration) were also measured before cold acclimation. Cold tolerance was then tested weekly during acclimation until no further change was observed. At this point, post-acclimation whole body physiological and histological variables were measured. This study defines the rate of change in cold tolerance under physiologically relevant conditions. Incorporating rate of change of commonly measured variables in thermal biology will help us better understand physiological responses to climatic shifts and invasion of novel environments.

P1-182 HARRIS, L*; CARRINGTON, E; HARRIS, Lyda; University of Washington; *lyharris@uw.edu*
The impacts of microplastic on the filter feeding of marine bivalves
Intertidal habitats are routinely exposed to varying levels of biotic and abiotic particles. As microscopic plastic (MP, plastic < 5mm) and sediment from runoff become more prevalent in our waters, it is important to determine if (and how) MP affects mussel physiology. We focused on mussels (Mytilus spp.), well-known filter feeder and bioindicator species that are known to ingest MP both in natural and laboratory settings. Silt and MPs are similar in size, lack nutritional value, and must be sorted from food, making the two abiotic particles an interesting and important comparison. Here we investigated mussel filtration rate response to current and extreme concentrations of MP exposure and how it compares to natural levels of algae and silt solutions. In all MP treatments mussels ingested and excreted MP as feces. Preliminary results suggest neither filtration rates in abiotic particle treatments deviate from algae-only treatments. In both abiotic particle treatments, mussels filter abiotic and biotic particles in equal proportions, however, in MP treatments pseudofeces containing MP are produced, indicating a selection against MP and not against silt. Comparisons among different bivalve species, increasing particulate concentrations, and potential implications will also be discussed.

P2-191 HARRIS, M*; AHMAD, A; PACE, CM; Le Moyne College; *harrismr@lemoyne.edu*
Flat On Its Back: Righting Mechanics of the Brown Marmorated Stink Bug.
The stink bug *Halyomorpha halys* is a pentatomid hemipteran characterized by a broad flat shield-like body. This morphology could constrain the methods by which *H. halys* rights itself. Beetles have been shown to right themselves using several mechanisms, but it is unknown if pentatomids show a similar variation in kinematics. Thus, how does a stink bug right itself? To address this question we used two high-speed cameras to capture the righting response of *H. halys* from both the top and lateral views and then quanitified kinematic and timing variables describing the movement. We found that *H. halys* primarily turns over via a forward flip (rather than a lateral roll or backward flip). Our preliminary results suggest that the movement can be broken up into two phases, a force generation phase (75% duration) and a falling phase (25% duration). At the start of the first phase *H. halys*'s hindmost pair of legs are spread wide and positioned anteriorly with the tarsal segments contacting the substrate. *H. halys* initiates movement by lifting its abdomen before positioning it against the substrate creating a tripod of support between the legs and the abdomen. As *H. halys* is positioning its abdomen it starts to elevate the anterior region of its body off the substrate and pivot forward, decreasing its stance width as it does so. When *H. halys* becomes perpendicular to the ground the second phase is initiated. During the second phase *H. halys*'s body falls forward onto its ventral surface. Hemipterans are a very diverse group and it is unknown how variation in body shape may affect their righting mechanisms. Investigating how different body shapes solve locomotor challenges, like righting oneself, is useful in understanding how locomotor contraints may by conferred by a particular morphology.

P2-172 HARRIS, MD*; DANIEL, TL; ROTH, E; Univ. of Washington; *monicah555@gmail.com*

Moths Regulate Body Attitude and Gaze to Stabilize Small- and Wide-field Visual Cues

Insect flight relies heavily on visual sensing. In many flight behaviors (e.g. navigating over long distances or through cluttered environments, finding food sources, or evading predators), insects must parse the visual scene to extract an estimate of their own motion and identify external objects or agents moving in their environment. Across numerous taxa and behaviors, there is a rich literature exploring behavioral responses to wide-field optic flow (visual stimuli arising from egomotion) and small-field target motion (cues corresponding to exogenous motion), primarily in the yaw dynamics involved in navigation. In contrast to yaw which is marginally stable, the equilibrium about pitch angle is inherently unstable, hence there are significant consequences to adjusting the flight attitude. To stabilize the visual scene under this constraint, insects can either reorient their body or move their head to redirect gaze. In this work, we investigate how the hawkmoth, *Manduca sexta*, modulates body pitch and gaze angle in response to wide- and small-field visual motion. Moths are tethered to a freely rotating armature at the center of a cylindrical arena and presented an image of circular flower (a figure subtending 18 deg azimuth) against a background grating (encompassing deg of the visual field). Figure and ground are oscillated both individually as well as simultaneously (both synchronously and incongruously). A multi-input—multi-output analysis reveals correlations that suggest moths employ parallel strategies for stabilizing posture and gaze dependent on the spatio-temporal content of the visual scene. The inherent instability in pitch dynamics necessitates these dual strategies.

P3-29 HARRIS, OK*; WOLFE, C; SPEISER, DI; University of South Carolina; *okharris@email.sc.edu*

Behind blue eyes: Structural color in the bay scallop Argopecten irradians

The field of biologically-inspired design is interested in photonic nanostructures that manipulate light to produce colors by preferentially scattering certain wavelengths. Structural color often results in iridescence because the angle of illumination influences how different wavelengths scatter. The iridescence of the blue eyes of the bay scallop *Argopecten irradians* invites the hypothesis that photonic nanostructures may be responsible for their appearance. To address our hypothesis, we used transmission electron microscopy to identify structures that may be associated with eye color in scallops. We found that epithelial cells from the blue eyes of the bay scallop *A. irradians* have three distinct layers: a distal layer of microvilli; a middle layer of small, tightly-packed, electron-dense spheres; and a proximal layer of much larger pigment granules. Computational modeling suggests that the size (120-140 nm in diameter) and packing density (60-80/μm^2) of the spheres are consistent with a maximal scattering of shorter wavelengths of light. Using energy-dispersive X-ray spectroscopy, we ruled out the possibility that these spheres are mineralized, suggesting that they are made of dense populations of proteins. In the epithelial cells from the black eyes of the sea scallop *Placopecten magellanicus*, we found a distal layer of microvilli and a proximal layer of pigment granulates, with no layer of spheres between them. We conclude that the iridescent blue color of eyes from *A. irradians* comes from the preferential scattering of short wavelengths by the small, tightly-packed spheres and the absorption of longer wavelengths by the pigment granules behind them. In future work, we will address the evolutionary history and ecological relevance of eye color in scallops.

P1-142 HARRIS-WEAVER, CS*; NG, J; BLOOM, D; LOVEJOY, NR; SUMMERS, AP; KOLMANN, MA; University of Washington, Western Michigan University, University of Toronto, Scarborough; *c.harrisweaver@gmail.com*

The Evolution of Feeding Morphology in Marine & Freshwater Needlefishes

The ecological opportunities that arise from marine to freshwater transitions are generally regarded as a driving force in the adaptive radiation of a variety of aquatic taxa. Radiations in marine-derived fish are evidenced by rapid diversification of behavioral and morphological adaptations largely pertaining to diet, followed by a slowing of these rates as niches are filled . Here, we study the transition in Needlefishes (Family Belonidae) and their close relatives the viviparous halfbeaks (Family Zenarchopteridae) from marine to freshwater systems and test whether the diversity and tempo of feeding morphological evolution have been substantially altered by these shifts. To compare the morphologies of these lineages, we use micro-computed tomography (μCT) scanning and Horos to obtain morphometrics of relevant characteristics pertaining to feeding. A principal components analysis is then used to visualize putative overlap or clustering of feeding morphologies in this theoretical 'morphospace' held by freshwater and marine needlefishes and halfbeaks. 20 species from the needlefish and halfbeak families are used to adequately study this system. Our results support our hypothesis, freshwater fish occupy a larger, more disparate, morphospace than their marine relatives. This is likely due to the variable and complex nature of freshwater habitats in addition to their geographical isolation allowing for a greater range of morphological adaptations in comparison to the more stable open sea environment.

P1-284 HARRISON, J.F.*; KASSI, A.; ADJERID, K.; AVILES, J.; KLOK, C.J.; VANDENBROOKS, J.M.; DUELL, M.E.; CAMPBELL, J.E.; ALANIS, E.; ABDO, C.; PENDAR, H.; HARRISON, Jon; Arizona State University, Virginia Tech, Virginia Tech; *j.harrison@asu.edu*

Gravity Effects on Hemolymph and Air Distribution in the Grasshopper, Schistocerca americana

The cardiovascular physiology of vertebrates is strongly affected by gravity, but possible effects of gravity on the open circulatory systems of invertebrates have been unstudied, possibly because it has been assumed that these would be negligible at small body sizes. We studied the effect of body orientation on the distribution of air and hemolymph in adult and juvenile grasshoppers, *Schistocerca americana*, using synchrotron x-ray imaging and radio-tracers. Regardless of age or size, changes in body orientation caused substantial gravity-driven blood flow and compression of lower air sacs and expansion of higher air sacs. Gravitational effects were greater when grasshoppers were anaesthetized by N_2, demonstrating that effects of gravity are actively resisted. Heart rates were higher in head-up vs. head-down animals, consistent with a compensatory baroreceptor response since grasshoppers hearts generally pump toward the head. Pressure differences between thorax and abdomen provided direct evidence for a functional valve that likely acts to restrict gravity-effects on hemolymph. These results suggest that, as for vertebrates, body orientation and gravity have strong effects on blood flow and physiology in terrestrial invertebrates. Supported by NSF IOS 1558052 and NSF EFRI BSBA 0938047.

P2-156 HARRISON, T*; GOTO, R; BOYLE, M; O'FOIGHIL, D; University of Michigan, Kyoto University, Smithsonian Marine Station; *tealh@umich.edu*

How do seven commensal bivalves share the same stomatopod host?

Seven species of yo-yo clams (*Divariscintilla* spp.) are burrow commensals of the mantis shrimp *Lysiosquilla scabricauda* in the Indian River Lagoon in Southeast Florida. This high-fidelity co-occurrence presents an ecological paradox given that closely related commensal galeommatoidean species typically associate with different hosts. I am interested in testing for latent niche differentiation among these co-occurring congeners, and am addressing this question using four different approaches: phylogenetic, ecological, behavioral, and dietary. A molecular phylogeny is being constructed to reveal sister relationships among the seven taxa. Extensive field surveys of host burrows have been taken to document ecological patterns of co-occurrence. One third of host burrows had commensals; one commensal species dominated often occurring by itself in high numbers, and up to four species were found together in mixed assemblages. Artificial burrow experiments are being used to infer possible microhabitat use among species, while behavioral experiments are being used to characterize commensal responses to host presence (chemotaxes) as well as other environmental cues (phototaxes, geotaxes, and thigmotaxes). Isotopic analyses of commensals and their environment (burrow water, burrow sediment and host) are being conducted to test for differential resource use among species (suspended organic matter, deposited organic matter, and host waste). At the time of writing, these lines of research are all in progress but there is evidence for clear niche differentiation in one sister taxon pair: an ectocommensal attaches directly to the host body while its sister species attaches to the host burrow walls. This micro-niche separation is associated with the evolution of morphological and behavioral differences, but it is not yet known whether it extends to dietary differentiation.

S7-7 HARROWER, JT; Univ. of California, Santa Cruz; *jharrower@ucsc.edu*

Seeking symbiosis: Linking art and science through symbiotic interactions

Human induced global change has triggered the sixth major extinction event on earth with profound consequences for humans and other species. To make progress towards protecting and effectively managing species and their complicated interactions, we need the support of a science literate public. Creating science inspired art is a useful strategy to connect people to difficult concepts at an emotional level and potentially increases public understanding of the current anthropogenic biodiversity crisis. Visual art can create a public space for dialogue around these difficult issues through the tools of narrative and powerful imagery. In my ecological work, I examine how symbioses could shape plant species' responses to climate change by studying the performance of iconic Joshua trees and their symbionts along a climate gradient, using both laboratory and field methods. With the results from this research I create multimedia art to communicate the concepts and findings of my science research to the public. Here I describe a variety of partnerships and collaborations that I have formed across art and science, discuss the benefits and tradeoffs, and make suggestions for successful approaches to this kind of interdisciplinary work.

S5-12 HARTMANN, MJZ; Northwestern University; *hartmann@northwestern.edu*

Sensory Feedback from the Vibrissal System During Exploratory Behaviors of the Rat

Rats are expert at navigating the world in the dark using their sense of touch. They rhythmically brush and tap about 60 large vibrissae (whiskers) against objects to determine size, shape, orientation, and texture. At the same time, rats also use their whiskers to help sense the direction of airflow, likely aiding in the localization of odor sources. In this talk I will describe the results of three recent studies that investigate how rats use whisker-based touch and airflow information to guide their exploratory behavior. The first experiment demonstrates that in a novel, unfamiliar environment, rats prefer to explore with their heads pitched to orientations that maximize the expected value of whisker contacts with a surface at an unknown distance. In other words, rats tilt their heads in a way that will tend to maximize the number of whiskers that will come into contact with a surface, given that the surface could be at any possible distance from the rat. The second experiment demonstrates that the relationship between right-left whisker asymmetry and head motion changes as the rat gains familiarity with the environment. Finally, the third experiment demonstrates that sensory feedback from the whiskers is important for anemotaxis. Five rats trained on a five-alternative forced-choice airflow localization task exhibited significant performance decrements after vibrissal removal. In contrast, vibrissal removal did not disrupt the performance of control animals trained to localize a light source. Simulation results suggest that changes in head pitch could aid in this airflow localization behavior. Together, these three studies lead to an understanding of rat exploratory behavior in which head pose is the primary factor that determines the overall spatial structure of input across the array, while individual whiskers drive the temporal structure that guides subsequent head movements.

P1-85 HARTZELL, SM*; PITT, AL; DAVIS, S; RIER, ST; Bloomsburg University of Pennsylvania, Trinity College, Hartford, CT, U.S. Fish & Wildlife Service Northeast Fishery Center, Lamar, PA; *seanhartzell77@gmail.com*

Invasive rusty crayfish (Orconectes rusticus) are more active diurnally than a native congener (Orconectes limosus)

Invasive crayfish can have a competitive advantage over native crayfish due to increased activity (defined as time spent outside of cover) in invaded environments, allowing for the acquisition of greater resources. We conducted an *ex situ* study to determine if total exposure time (a proxy for activity and defined as time spent outside of shelter regardless of behavior) and behavior (i.e., walking; immobile) differed between native spiny-cheek crayfish (*Orconectes limosus*) and invasive rusty crayfish (*Orconectes rusticus*) from the Susquehanna River drainage in Pennsylvania. We conducted the study in raceways modified to simulate a typical stream within the Susquehanna River drainage, inclusive of a native, nocturnal predator, the eastern hellbender (*Cryptobranchus alleganiensis alleganiensis*). We recorded video in each raceway and collected data from the video including total exposure time and duration of walking and immobile crayfish behaviors. There were no significant nocturnal differences between crayfish species in total exposure time ($w=13668$, $df=338$, $p=0.44$), walking behavior ($t=0.4478$, $df=160$, $p=0.65$), or immobile behavior ($t=-1.5687$, $df=176$, $p=0.11$), suggesting both species behave similarly at night. Diurnally, rusty crayfish had significantly greater total exposure time ($w=235.5$, $df=70$, $p<0.01$) and spent significantly more time walking ($t=-4.4424$, $df=30$, $p<0.01$) and immobile ($t=-4.350$, $df=37$, $p<0.01$) than spiny-cheek crayfish. This suggests invasive rusty crayfish may have an indirect competitive advantage over native spiny-cheek crayfish due to differences in diurnal behavior.

49-1 HARVEY, C*; BALIGA, VB; LAVOIE, P; ALTSHULER, DL; University of British Columbia, University of Toronto; *harvey@zoology.ubc.ca*

How elbow deflection affects the aerodynamic performance and stability of gliding gulls at varying turbulence conditions

Wing morphing allows birds to modify their aerodynamic performance and stability in flight, mediating the effects of fluctuating environmental conditions. Morphing is achieved through manipulation of the elbow and wrist joints, resulting in wing shape changes. Although previous research has shown that wrist flexion, manifested as sweep, improves high-speed and turning performance, there is no quantitative evidence demonstrating the effect of elbow angle on performance or stability. Further, for gliding flight, little information exists linking environmental turbulence, wing morphing characteristics, and aerodynamic parameters. To approach these questions, we first observed gulls in gliding flight and quantified their wing shapes. We, next, used cadavers to determine the range of elbow angles and the subset of angles used in glides. Finally, we evaluated the aerodynamic consequences of morphing configurations by preparing gull wings at different elbow angles, which were tested in a wind tunnel at varied turbulence intensities. We found evidence that elbow angle has a direct effect on aerodynamic efficiency, pitching stability, adverse yaw and the zero-lift pitching moment of the wing. This indicates that through elbow deflection alone, birds are capable of altering their glide performance and stabilization. Turbulence intensity affected aerodynamic efficiency and zero-lift pitching moment and additionally, maximal lift production. Relating the experimental results back to the morphed shapes used in gliding flight, we can identify a suite of aerodynamic benefits used by gliding gulls, and define how this is affected by a turbulent environment.

P2-184 HATCH, ST*; CIERI, RL; BRAINERD, EL; University of Utah, Brown University; *samthatch@aol.com*

XROMM analysis of axial skeletal kinematics during terrestrial locomotion in the savannah monitor, Varanus exanthematicus

The axial skeleton serves as the chassis for both ventilation and locomotion in tetrapods. Questions remain, however, about the role of the axial skeleton in generating locomotor work. In lepidosaurs, lateral bending of the axial skeleton may serve to increase stride length by placing each limb further forward than it would land without bending. The axial skeleton may also directly generate locomotor work if the lateral bending pushes the animal's center of mass forward relative to limb support. The relative motions of the vertebral column and ribs during locomotion, which could help to examine these roles, have not yet been measured in a tetrapod during locomotion. One null hypothesis for these movements could be that each vertebra rotates relative to adjacent vertebrae around a dorsoventral axis, with the ribs moving relative to each other but not moving relative to the vertebrae at the costovertebral joints. To test this null model we measured the relative motions of vertebrae, ribs, and the sternum during treadmill locomotion in the savannah monitor using marker-based and markerless X-ray reconstruction of moving morphology (XROMM). During a typical stride, as predicted, the vertebrae rotated towards each other around a dorsoventral axis, producing concave spinal curvature ipsilateral to front limb support. In contrast to the null model, however, costovertebral joint rotations included positive caliper motion, with the ribs lifted dorsally towards the vertebral column, and positive and pump handle rotation, such that the ipsilateral ribs elevated and folded caudally during the propulsive phase of the ipsilateral front limb. Continued study of axial kinematics during locomotion are critical to understanding the evolutionary pressures on the design of the vertebrate chassis.

87-6 HAVENS, L T*; SPEISER, D I; University of South Carolina, Columbia; *lukethavens@gmail.com*

Assessing an automatable protocol for electrophysiological measurement of spectral sensitivity

Understanding the physiological limits of an animal's visual system is an important part of studying their visual ecology. Without first determining what an animal is physiologically capable of perceiving, it is difficult to ascertain what visual information in its environment could have behavioral significance. An effective way to assess the physiology of visual systems is via direct recording of the electrical activity of photoreceptors using a technique known as electroretinography (ERG). But accurate ERG can be time and labor intensive, often involving manual adjustment of the wavelength and intensity of light stimuli and real-time comparison of physiological responses to inform those adjustments. Furthermore, because stimulus adjustment can involve its own skillset, ERG often requires expertise beyond that necessary for the electrophysiological preparation itself. To improve both the efficiency and accessibility of ERG, we designed a highly automatable protocol leveraging wavelength-dependent changes in temporal acuity to assess animals' spectral sensitivity. Rather than determining spectral sensitivity by comparing the electrical response intensities between different wavelengths of light, our protocol assesses spectral sensitivity by comparing flicker fusion frequency between intensity-balanced wavelengths: decreased flicker fusion frequency suggests lower sensitivity to a wavelength. To utilize this protocol, we designed an automated stimulus presentation and data acquisition system for ERG. Here we compare our new technique to conventional approaches using classical electrophysiological model organisms to assess its merit.

69-2 HAVIRD, JC*; NOE, GR; LINK, L; TORRES, A; SLOAN, DB; HAVIRD, Justin; Colorado State Univ.; *justin.havird@colostate.edu*

Do Mitonuclear Interactions Prevent Hybridization in a Lineage with a History of Mitonuclear Coevolution?

The genomes of mitochondria, plastids, and other endosymbionts have long been hypothesized to play a role in creating reproductive isolation between species. One general mechanism to explain the role of mitochondrial (mt) genomes in creating reproductive isolation is the propensity for mt genomes to accumulate slightly deleterious mutations. If mt mutations exert selective pressure for corresponding changes in nuclear-encoded genes (i.e., mitonuclear coevolution), then coadapted mitonuclear genotypes would arise within lineages. Epistatic interactions among coadapted mt- and nuclear-encoded genes might therefore be compromised in hybrids, leading to hybrid breakdown and reproductive isolation. We have previously documented pervasive signatures of mitonuclear coevolution in the angiosperm genus *Silene*, and here we explore whether compromised mitonuclear interactions in *Silene* hybrids cause reduced fitness and mt function. Through backcrossing experiments, hybrids were generated that possess either control or "mismatched" cytonuclear genotypes. Survival, growth, and reproduction were then quantified in the resulting hybrids. Detailed measurements of substrate-coupled respiration and other metrics of mt function were also performed in isolated mitochondria. Although there was variation between genotypes in organismal fitness and mt function, none of our measurements indicated that mismatched hybrids had reduced fitness or altered mt function. While these results do not rule out the possibility of a role for cytonuclear interactions in reproductive isolation (even within *Silene*), they highlight important questions that have been raised about the ubiquity of cytonuclear coevolution in the creation of species boundaries.

P2-33 HAWKINS, TM*; ARCHER, J; DAVIS, JE; Radford University; *thawkins18@radford.edu*

Effects of Royal Jelly in Combination With Juvenile Hormone Agonists and Antagonists on Drosophila melanogaster

Previous research has shown that administering Royal Jelly (RJ) to the fruit fly (*Drosophila melanogaster*) results in an increase in growth rate along with several changes to development. However, the combined effects of RJ and another hormonal modulator of growth, Juvenile Growth Hormone (JH), have formerly been overlooked. Royal Jelly has been linked with increased ovary size and hastened turnover time from youth to functioning adult (Kamakura, 2011). Conversely, JH maintains adolescent morphology and physiology in juveniles and increases reproductive output (via vitellogenesis) in adults. Here we describe our studies on the effects of RJ combined with both JH agonists and antagonists. We studied the impact of these hormonal combinations on both larval and adult fruit flies and will report on effects on morphology, developmental time course, and mortality.

P3-132 HAWKINS, C.E.*; PALIA, S.T.; FOLKS, C.C.; SWADDLE, J.P.; College of William & Mary; *cehawkins@email.wm.edu*

Investigating the effects of anthropogenic noise disturbance on songbird social networks

Anthropogenic noise, which is increasing globally, affects birds from gene expression up through alteration of community composition. At the behavioral level, noise often disperses birds away from the point source. The impacts of this dispersal on surrounding quieter areas is not well understood. Therefore, in this project, we sought to understand how noise-related dispersal affected the sociality of groups of songbirds as they moved away from the source of noise. As the displaced birds would likely be forced to occupy a smaller area that may already have resident individuals, we predicted that displaced birds would show a more clustered social network that may include new individuals, and that individuals within the flock would have more social connections overall. We tested these ideas in two songbird systems, captive domesticated zebra finches (*Taeniopygia guttata*) and free-living red-backed fairy wrens (*Malurus melanocephalus*). Preliminary results indicate that networks became more clustered during experimental sound treatments and lost connectedness in the period following a sound treatment. Free-living birds seemed to shift their territory away from the sound source, and only some individuals returned to the original territory following the sound treatment. If social networks are altered consistently, there may be implications for future breeding success, detection of communication signals, and even for pathways of disease transmission among individuals.

P2-136 HAYE, PA*; SEGOVIA, NI; GALLARDO-ESCáRATE, C; U. Católica del Norte, Depto. Biología Marina, Coquimbo, Chile; INCAR, U. de Concepción, Chile, INCAR, U. de Concepción, Chile; *phaye@ucn.cl*

Seascape Genomics in the Tunicate Pyura chilensis

Seascape genomics evaluates the relationship between oceanographic variables and genetic structure within species through environmental association of genetic markers. We used SNPs scattered through the genome in the tunicate *Pyura chilensis*, a benthic species endemic of the SE Pacific coast, to infer neutral and adaptive spatial genetic structure of six local populations between 24º and 42ºS. Neutral structure was consistent with previously detected divergence with COI sequences at the 39ºS site. The remaining sites showed low genetic differentiation in spite of the low capacity of larval dispersal of *P. chilensis*, consistent with anthropogenic mediated dispersal in boat hulls. Adaptive SNP loci showed a different main signal that consisted on a genetic discontinuity between the sites at 29ºS and 36ºS. In that area, at 30ºS, there is a well-known biogeographic break, a region of high upwelling in which many species have a concordant phylogeographic break with COI (not *P. chilensis*). The genetic structure at ca. 30ºS in *P. chilensis* has only been detected with adaptive loci. We analysed the relationship between relevant oceanographic variables and the genetic structure and found that adaptive structure was significantly associated to variables related to upwelling and high productivity, most significantly with sea surface temperature. The seascape genomics approach detected a role of natural selection in structuring adaptive diversity; it was consistently associated to environmental variables that showed a discontinuity at 30°S, and suggests that upwelling shapes adaptive divergence spatially concordant with the 30°S biogeographic break. Funding: Fondecyt 1140862 & FONDAP INCAR 15110027.

133-2 HAYFORD, HA*; GEORGE, MN; CARRINGTON, E; University of Washington; *hayford@uw.edu*

Experimental Ocean Acidification Inhibits Snail Growth

Chemical changes associated with ocean acidification can affect the physiological processes underlying performance of aquatic organisms. The interaction of the ocean's multifaceted carbonate system with numerous biological pathways makes teasing out mechanisms very complex. Traditionally, whole-organism metrics of performance, such as growth, have been used to estimate the net biological effect of these mechanistic factors. Using this metric, we hypothesized that under high CO_2/low pH conditions, animals would experience an increased energetic demand leading to decreased growth. Natural pH fluctuations in tidally-driven nearshore areas make intertidal animals model organisms for understanding pH tolerance. We subjected the intertidal snail *Nucella ostrina* to six different levels of seawater pH, ranging from 7.0 to 8.0 on the total scale (pCO_2 5892-288 µatm), in indoor aquaria at the Ocean Acidification Environmental Laboratory of Friday Harbor Labs. We measured snail consumption of its barnacle prey and snail shell and tissue growth over 6 wk. We were surprised to observe that with decreasing pH, snails consumed more barnacles. Snails in the pH 7.0 treatment consumed nearly 50% more than snails in the ambient treatment (pH 7.8). Snail growth was similar in all treatments, with a trend towards reduced growth at pH 7.0. At low pH, growth was inhibited relative to food intake. We inferred that unmeasured costs associated with ocean acidification outweighed benefits. If snail feeding increases with reduced pH due to ocean acidification, the interaction strength between this snail and its barnacle prey may be increased. However, this increase in predation would not benefit the snail as it does not yield higher growth.

P3-57 HE, JY*; WICTOR, EP; THOMAS, EO; Univ. of the Pacific; *j_he6@u.pacific.edu*

Analysis of Venom Proteins in Corydoras Catfish

In the tropical fish pet trade, transportation and movement can subject fishes to prolonged stress. In response to these stressors, some species of catfishes are known to release defensive secretions which cause self-poisoning and death. The chemistry of these toxic secretions are unknown. We are interested in identifying and studying the venoms of *Corydoras* catfishes, a genus that is also a common household pet. Venom secretion was induced by stressful handling of the fish. Within minutes, the water turned cloudy, indicative of venom secretion. Signs of self-poisoning were evident when fish showed reduced vitality. Analysis of *Corydoras* venom through SDS-PAGE, Bradford Standard Assay (BSA), and Mass Spectrometry confirmed that the venom secretions consist of multiple protein compounds. Through Mass Spectrometry, a homology of certain polypeptides found in venom secretions of multiple *Corydoras* was found. The chemical diversity of the venom compounds is being explored in multiple *Corydoras* species. In conjunction with the chemical analysis, we are studying the anatomical structure of the venom glands through gross anatomy and histology analysis. Through gross anatomy, a gland was found proximal to an opening where secreted venom may empty through. Through histology analysis, we have been able to locate where ducts could potentially be at as well as nerve endings and vesicles possibly containing venom granules allowing us to elucidate the mechanism of venom secretion. While ongoing studies are still occurring, we have taken many steps that has allowed us to understand the unknown properties of *Corydoras* venom as well as the the general physiology and anatomy of *Corydoras* venom gland. With these studies taken together, our hope is to elucidate the functions of the venom and the degree of evolutionary homology within *Corydoras* genus.

P3-143 HEARST, LW*; MILLER, AL; University of Tampa; *laura.hearst@spartans.ut.edu*

Evolution of Eye Size in Scorpions

The evolution of eye size has been studied across multiple taxa. In general, predators evolved larger eye size per body mass as an adaptation for locating their prey and some prey evolved large eyes, increasing their visual acuity as they flee from their predators. Most research on invertebrate eye size have focused on species with high visual acuity. Consequently, little attention has been given to the evolution of eye size in scorpions, which have limited vision. Scorpions are nocturnal predators that rely primarily on specialized setae to detect substrate and air vibrations of their prey. However, the persistence of the eyes in most scorpion species suggests the eyes are functional, albeit not for prey capture. Research has shown the eyes of scorpions are sensitive to changes in ambient light and may assist with celestial navigation and circadian rhythms. Although many scorpions are desert inhabitants, others occupy a variety of habitats, including environments with significant canopy cover. Therefore, we wanted to test if there were eye morphology adaptations to these different environments. This research tested the relative size of the median eyes in two scorpion species that inhabit different environments, with different levels of ambient light available. It was predicted that scorpions in a forested habitat evolved larger eyes in the lower light environment. The diameter of the eye and the carapace length of fifty-six specimens total, were measured. Controlling for carapace length (measure of body size), eye size was larger in the scorpion species that occupies a forested environment compared to the desert species. Our findings suggest that it may be advantageous to have larger eyes if in an environment with significant canopy cover.

P3-186 HECK, C*; WOODWARD, H; Oklahoma State Univ. CHS, Tulsa; *ctheck@okstate.edu*

The Extent of Metaplastic Hard Tissue in the Limbs of the Nine-Banded Armadillo (Dasypus novemcinctus

The developmental and functional advantages of vertebrate metaplastic hard tissue is still relatively unclear. Metaplastic tissue forms from direct transformation of one cell type to another. Specifically, mineralization of preformed dense connective tissue results in intratendinous metaplastic tissue, and has been described in a variety of taxa and elements including dinosaur cranial elements, ossified tendons, and tendinous entheses. Histological analysis of the extent of metaplastic hard tissues, both across Mammalia and within individual mammalian bones, is lacking. Here we serially sectioned both tibiae and humeri of a nine-banded armadillo, *Dasypus novemcinctus* [Xenarthra: Cingulata], to identify the existence and patterns of metaplastic tissue. We found metaplastic tissue extensively throughout the diaphysis of both elements, primarily at sites of muscle attachments. The presence of metaplastic tissue in the tibiae and humeri seems consistent with tendinous insertions through fibrous entheses along the length of the two elements. We also found metaplastic tissue interstitially deep in the cortex of both elements. The entrapment of metaplastic tissue within the cortex is likely due to appositional bone growth at the enthesis. However, we also found metaplastic tissue interstitially in regions unassociated with tendinous entheses. Previously, unassociated metaplastic tissue was found extensively in osteoderms and dinosaur cranial ornamentation such as the parietal frill of *Triceratops*. Study of metaplastic tissue in modern bone, independent of tendinous insertions, can improve our understanding of its potential biomechanical advantages and thereby possibly provide clues to its use in ornamentation.

P2-34 HECK, MJ; HATLE, JD*; Univ. of North Florida; *jhatle@unf.edu*

Neuropeptide F, short Neuropeptide F, or feeding level each can regulate oxidative damage of proteins in grasshoppers

Aging is characterized by the accumulation of biomolecular damage, which leads to reduced function. Dietary restriction extends lifespan in many species, and the feeding stimulant hormone Neuropeptide F (NPF; homolog of NPY in vertebrates) is hypothesized to participate. A few studies have shown that NPF/Y improves proteostasis. Here, we test whether supplemental NPF and feeding level interact to reduce accumulation of carbonyls (oxidized proteins). For 32 d prior to dissection, middle-aged female grasshoppers were reared either on life-extending dietary restriction or an ad libitum diet. Grasshoppers on dietary restriction typically consumed all their daily food in 5-6 h. For 16 d prior to dissection, grasshoppers were injected daily with either 100 pmol truncated NPF (YSQVARPRFa), truncated shortNPF (SPSLRLRFa), or water. Grasshoppers were fed in the morning and injected in the afternoon. This temporal separation avoided weakening of the peptide signal by responsive feeding. In ad libitum-fed grasshoppers, injection of NPF, but not shortNPF, increased feeding on 5 of 6 days tested ($P<0.05$). Carbonyls were analyzed by immunoblot. In gut, carbonyl levels were reduced by dietary restriction ($P>0.0001$) and by shortNPF injection ($P=0.0016$), but not their interaction and not by NPF. In fat body, there was a significant interaction of feeding level and injection type ($P<0.0001$); upon ad libitum feeding either shortNPF or NPF increased carbonyl levels, but upon dietary restriction NPF decreased carbonyl levels. In head neural tissues, neither feeding level nor injection affected carbonyl levels. These results suggest that NPF with dietary restriction, or perhaps shortNPF alone, can reduce protein oxidation in specific tissues. These results are consistent with NPF and shortNPF contributing to biomolecular maintenance and longevity.

37-3 HEDRICK, MS*; HILLMAN, SS; California State University, East Bay, Portland State University;
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A Metabolic Hypothesis for the Evolution of Temperature Effects on the Arterial PCO_2 and pH of Ectothermic Vertebrates

Temperature increases in ectothermic vertebrates lead to increases in arterial PCO_2 ($PaCO_2$) and declines in arterial pH (pHa) of about 0.017 pH units/°C increase in temperature. This pattern acid-base regulation occurs because minute ventilation does not keep pace with metabolism (VO_2), resulting in a relative hypoventilation and the observed changes in $PaCO_2$ and pH. The regulation of ventilation with temperature and the alphastat pattern of pH has been interpreted as being adaptive for maintaining a constant protonation state on the imidazole moiety of histidine protein residues hence stabilizing protein structure-function. Analysis of the existing data for interclass responses of ectothermic vertebrates show different degrees of $PaCO_2$ increases and pH declines with temperature between the classes with reptiles > amphibians > fish. The slopes (units/°C) of the relationship between pHa and temperature for reptiles, amphibians, and fish were -0.014, -0.013 and -0.010, respectively, all below the -0.017 units/°C slope characteristic of alphastat regulation. The $PaCO_2$ at the temperature where maximal aerobic metabolism (VO_{2max}) is achieved was significantly and positively correlated with temperature for all vertebrate classes. For ectotherms, the $PaCO_2$ where VO_{2max} is greatest is also correlated with VO_{2max} indicating there is an increased driving force (ΔPCO2) for CO_2 efflux that is lowest in fish, intermediate in amphibians and highest in reptiles. We hypothesize that the pattern of increased $PaCO_2$ and the resultant reduction of pHa to increased body temperature primarily serves to increase CO_2 efflux, O_2 delivery, blood buffering capacity and maintain ventilatory scope with changes in temperature or activity. This represents a new hypothesis for the selective advantage of $PaCO_2$ and pHa regulation in ectothermic vertebrates.

116-2 HEERS, A. M.*; TUCCI, E. R.; LENTINK, D; Stanford University; *ashmheers@gmail.com*

A musculoskeletal model of the avian flight apparatus: spring-like qualities of the pectoralis and supracoracoideus muscles

Tendons and other connective tissues in muscles are thought to play a dynamic role in many types of locomotion. By storing then releasing elastic energy, connective tissues can reduce metabolic costs and amplify power output. Such benefits are increasingly well documented in vertebrates for terrestrial, but not aerial, locomotion. One explanation for this discrepancy is that elastic mechanisms are less prevalent during aerial locomotion, because air does not provide a ground reaction force that can be absorbed and stored by muscle-tendon units. In birds, however, many flight muscles have long tendons, and some of these are hypothesized to facilitate powered flight by stretching then recoiling in opposition to each other, to decelerate then accelerate the wing during downstroke-upstroke or upstroke-downstroke transitions. To test whether these muscle-tendon units can recover useful elastic energy, we constructed a three-dimensional musculoskeletal model of the Collared-Dove (*Streptopelia*) and used simulations (OpenSim) to explore muscle-tendon dynamics during flight. Coupled with previous work on Chukar Partridges (*Alectoris chukar*) and *in vivo* kinematics and aerodynamic force measurements, our simulations suggest that the two main flight muscles of birds, the pectoralis (downstroke) and supracoracoideus (upstroke), have spring-like qualities. Both muscles produce force that decelerates then accelerates the wing, transitioning from negative to positive power in opposition to one another. These findings corroborate previous hypotheses and suggest that passive connective tissues in the pectoralis and supracoracoideus act as antagonistic springs that help birds meet the high power requirements associated with flapping flight.

19-2 HEIDINGER, BJ*; SLOWINSKI, SP; SIRMAN, AE; KITTILSON, J; GERLACH, NM; KETTERSON, ED; North Dakota State University, Indiana University, University of Florida;
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Experimentally elevated testosterone increases telomere loss in a songbird

Reproductive investment often comes at a cost to longevity, and in male vertebrates, testosterone is expected to play a role in governing this trade-off. However, the mechanisms linking elevated testosterone exposure with reduced survival remain poorly understood. Telomeres, a mechanism of cellular and organismal aging, may be important in this context. We experimentally tested the hypothesis that exposure to elevated testosterone accelerates telomere loss in a free-living population of dark-eyed juncos (Junco hyemalis carolinensis). Previous research in this system has demonstrated that males with experimentally elevated testosterone sire more offspring, but have lower survival than controls. Here we measured telomere length and loss in known-age males that had received testosterone or control implants and found that males with experimentally elevated testosterone experienced significantly more telomere loss and tended to have shorter telomeres than controls. These results are consistent with the hypothesis that testosterone reduces longevity in part through its effects on telomeres. Given that both testosterone and telomeres are relatively conserved in vertebrates, this could be an important part of the mechanistic pathway underling the cost of reproduction.

39-4 HEIM, N.A.*; PAYNE, J.L.; Stanford University;
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Estimating Global Extinction Threat Levels in Butterflies

Butterflies are charismatic mesofauna that are sensitive to environmental change and have great potential to inspire conservation mindsets in the general public. We present the results of a macroecological analysis of extinction threat in 6797 species of butterfly (Order Lepidoptera, Suborder Rhopalocera). We used the IUCN threat status of 276 species to create a logistic regression model of extinction threat using body size, geographic range, habitat specificity, rarity (assessed by date of last known observation), and several bioclimatic variables as predictors. We find that body size has very little predictive power for extinction risk, consistent with the hypothesis that size-selective extinction is a signature of human hunting rather than habitat or climate changes. Family membership, geographic range, and rarity are the strongest predictors of extinction threat. Butterflies are one of the best-represented invertebrate groups on IUCN's Red List. Nevertheless, a very small percentage of known butterfly species have been evaluated. To develop a better sense of global butterfly extinction risk, we applied the regression model to 6521 butterfly species that have not yet been evaluated by the IUCN. The IUCN lists 29% of butterfly species as being vulnerable or more threatened. We find that that the most threatened 29% of unevaluated species have a threat probability of at least 0.24. Moreover, the threat probability is greater than 0.50 for 12.5% of species and greater than 0.75 for five percent of species. Overall extinction threat in butterflies is currently low based on calibration from assessed species; however, ongoing climate change and loss of habitat are likely to cause threat levels to increase across the coming decades.

99-7 HEIN, A M; GIL, M A*; NOAA; Univ. of California, Santa Cruz, Univ. of California, Davis; *andrew.hein@noaa.gov*

Measuring and modeling the escape response of wild fish

When responding to acute threats such as an attacking predator, animals must rapidly filter and integrate diverse sensory cues to produce a robust escape response. In fish, this is accomplished at least in part through a set of neural circuits in the brain, which, when triggered, produce a reflex-like flight response. While these flight responses have been studied in detail in the laboratory, studying responses of fish in the wild has proven far more challenging. We developed an experimental platform for performing behavioral experiments on wild, freely swimming fish. We show that a combination of visual and acoustic stimuli reliably trigger short-latency escape responses in a diverse range of fish species, but that these responses are continually modulated based on incoming sensory input, allowing fish to produce robust but flexible reactions to threats.

P3-244 HEKKALA, ER*; AMATO, GA; NORELL, M; RUSSELLO, M; GATESY, J; Fordham University/AMNH, New York, American Museum of Natural History, New York, University of British Columbia, Okanagan; *ehekkala@fordham.edu*

An Extinct Crocodile Provides Keys to Understanding to Origins of Crocodylus

Ancient DNA from three subfossil crocodile specimens of *Crocodylus (Voay) robustus* (Grandidier & Vaillant, 1872) from Madagascar was used to determine the phylogenetic placement of this species within extant crocodilians. This species was recently separated from Crocodylus and placed in its own genus, Voay (Brochu 2007) based on similarities in cranial features shared with the African dwarf crocodile (genus Osteolaemus). The species' phylogenetic position is particularly interesting with respect to the recency and circumstance of its extinction, which appears to be coincident with the arrival in Madagascar of both humans and the extant Nile crocodile (*Crocodylus niloticus*). Genomic DNA derived from subfossil material was used to create a library for next generation sequencing using whole genome enrichment and targeted sequence capture. A phylogenetic analysis of the largely intact mitogenome places the extinct species as basal to all true crocodiles (*Crocodylus ssp.*) and outside of the clade containing Osteolaemines. These results suggest that the ancestor of the true crocodiles may have arisen in isolation after widespread extinction of crocodilians during the Miocene. Our results further suggest that competition with recently arrived Nile crocodiles may have contributed to the species' demise.

P3-180 HELLERT, SM; Indiana University; *shellert@umail.iu.edu*

Understanding the Causes of Phenotypic Integration Patterns in Birds Limbs

Phenotypic trait integration strongly controls the strength and direction of natural selection. Traits covary due to genetic/developmental factors (e.g. two traits influenced by one gene) or functional factors (e.g. two traits of the same biomechanical apparatus). Historically, these underlying factors of trait integration have been very difficult to tease apart, but understanding the relative contribution of these factors is important, because they determine how much of an effect selection can have on an animal's phenotype. Studies on integration determinants in vertebrates have been largely limited to mammal skulls and jaws. Studying the integration within and among limb elements of flying and flightless birds provides an opportunity to more fully understand sources of phenotypic evolutionary constraint in a very different taxonomic group. Birds have become flightless many times, offering natural repetition of this transition. Intriguingly, despite independent evolutionary routes to flightlessness, flightless birds share similar skeletal limb element proportions and an affinity for sexual dimorphism of body size. In this study, I compared shared traits of flightless birds to the patterns of trait integration seen in the limbs of flightless and flying birds to distinguish genetic/developmental from functional factors of trait integration for the first time. The results show the limb integration patterns of flightless birds diverge from a shared pattern of flying birds. This suggests a functional cause of integration (flight) rather than conserved, intrinsic mechanisms that constrain the phenotype of all bird limbs regardless of flight ability. Once biomechanical pressures of flight have been released in flightless birds, skeletal traits can reorganize into new patterns of integration, which can impact how phenotype responds to sexual selection.

53-7 HELLMANN, JK*; BELL, AM; University of Illinois, Urbana-Champaign; *jehellmann45@gmail.com*

Sex-specific effects of maternal and paternal experience with predation risk in threespined sticklebacks

Organisms can gain information about their environment via their own personal experience or via information that's provided by their parents. A central problem, though, is how individuals integrate information from different sources. Cues may be additive, such that individuals who receive both personal and parental cues about their environment may have twice the phenotypic consequences as individuals who only receive cues from one source. Alternatively, individuals with multiple cues may just ignore redundant information. Here, we seek to understand how both parental and personal experience with predation risk alter offspring traits in threespined sticklebacks *Gasterosteus aculeatus*. In a 2x2 factorial experiment, we exposed mothers, fathers or both parents to a model predator prior to fertilization in order to evaluate the role of maternal and paternal experience with predation risk on offspring traits. At two months of age, half of the offspring were exposed to a model predator to compare the effect of personally versus transgenerationally-acquired information about predation risk on offspring traits. We found that offspring are more responsive to the experiences of their same-sex parent: daughters alter their behavior with respect to maternal experience while sons alter their behavior with respect to paternal experience. Moreover, personally and transgenerationally-acquired information elicited the same response: offspring displayed similar behaviors when they were directly exposed to predation risk or when their same-sex parent was exposed to predation risk, or when they received both cues. These results suggest that there are sex-specific effects of parental experiences in sticklebacks and highlight the importance of parents' experience prior to fertilization for their offspring.

P2-108 HELLWIG, MD; University of Rhode Island; *hellwig@uri.edu*

Inferring Gene Ontology from Phylogenetic Species Displacement

Determining the biological functions of genes can greatly improve our understanding of evolutionary tendencies. By better understanding the relationships between mutations in DNA sequences and the occurrence or absence of particular traits or diseases, we can also greatly accelerate medical advancements - particularly in individualized medicine. However, determining these functional relationships requires complex and time consuming procedures, often including invasive tests in live animals. Here I introduce a method to infer candidate genes by analyzing large amounts of incomplete DNA sequences across large sets of species.

First, I construct gene trees for each considered locus. Loci need not be genes, but usually will be. As some data will not be available, the sets of species included in gene trees will vary. The consensus tree, however, will include all of them. I then compare each species' position within the consensus tree against its position in each gene tree in which it is present and record its relative displacement. This results in an incomplete displacement matrix.

Simultaneously I derive a large number of morphology trees based on observations of morphological traits. These can be expressed as Boolean or numerical values. Similar to the previously described approach I obtain a morphological displacement matrix which may also be incomplete.

In a final step I explore existing correlations between the two matrices that indicate which genes might be directly or indirectly influencing particular traits. This method does not aim to determine gene functionality by itself, but it will facilitate investigative research by focusing efforts on likely candidate genes. It can be completed on limited computing architecture, even when analyzing very large sets of data.

139-1 HELM, BR*; RINEHART, JP; YOCUM, GD; GREENLEE, KJ; BOWSHER, JH; HELM, Bryan; NDSU, Biological Sciences, Fargo, ND, USDA-ARS Insect Genetics and Biochemistry, Fargo, ND; *bryan.r.helm@ndsu.edu*

Flight biomechanics of developmentally-induced size variation in the solitary bee Osmia lignaria.

Body size covaries with morphology, functional performance, and fitness. For insects, variation in adult phenotypies are derived from developmental variation in larval growth and metamorphosis. In this study, we asked how larval growth impacted adult morphology in *Osmia lignaria*—especially traits that are critical for pollinator performance. We altered the duration of larval growth by manipulating the quantity of food provisions larvae could consume. This induced twice the variation in body size that is observed in natural populations, and caused a 10-fold difference between smallest and largest adult bees. We then examined the consequences of developmental variation on adult morphology. Allometric relationships between body size and body segment mass (head, thorax, abdomen) were examined to see how developmental variation altered body trait relationships. Second, morphometrics that are critical for flight performance (wing area, wing loading, and an extra flight power index) were quantified. We found that the head and thorax scale hyperallometrically with size. However, abdominal mass and wing area increased hypoallometrically with body size. Allometric patterns were affected by sex to some degree. For flight metrics, wing loading was reduced in small adults, and differences in the extra flight power index suggested that small *O. lignaria* adults were capable of more excess flight power than large adults. These results suggest that developmental variation alters morphometric trait relationships in adult insects that may lead to functional differences in performance.

P2-121 HENDERSON, EC*; CLARK, CJ; BRELSFORD, A; Univ. of California, Riverside; *ehend004@ucr.edu*

Genome-wide Analysis of Differentiation in a Pair of Hybridizing Hummingbirds

Speciation is a central issue in evolutionary biology, and the study of genomic mediators of speciation has emerged in recent years with advances in DNA sequencing techniques. These studies often uncover heterogeneous patterns of genetic differentiation, but the interpretation of these patterns remains controversial. Do regions of high differentiation contain "barrier loci" that reduce gene flow between the species, or do they reflect low variation resulting from within-species selection? Here, we document patterns of genetic differentiation between two hybridizing bird species, Anna's and Costa's hummingbirds, using whole-genome sequence data. By comparing differentiation between sympatric and allopatric populations, we aim to identify regions of the genome that contribute to reproductive barriers, and quantify the influence of hybridization on the genome of each species. These results will increase our understanding of the complex process of speciation.

19-6 HENNIN, HL*; LEGAGNEUX, P; GILCHRIST, HG; JANSSEN, MH; BÊTY, J; LOVE, OP; University of Windsor, Windsor, ON, Université du Québec à Rimouski, Rimouski, QC, National Wildlife Research Centre, Environment Climate Change Canada, Ottawa, ON, National Wildlife Research Centre, Environment Climate Change Canada, Ottawa, ON; *hollyhennin@gmail.com*

Physiological Mechanisms Driving Foraging, Fattening and Reproduction in an Arctic Seaduck

Reproduction is an energetically demanding life history stage in which individuals must carefully manage energetic resources. Species reliant on capital stores for reproduction are under a unique set of constraints because they must accumulate substantial fat stores prior to reproducing; however, the underlying mechanisms influencing the accumulation of resources are currently poorly understood. Corticosterone (CORT) is an energetic hormone that influences resource acquisition and management, making it a strong candidate mechanism linking foraging behaviour, resource acquisition, and reproductive decisions. We implanted wild-living females with either a control or a dose of CORT to elevate plasma levels within a baseline range and deployed GPS units in Arctic-nesting common eiders, a mixed capital-income breeding strategy species. We quantified foraging behaviour and followed our hens through to reproduction to determine the effects of baseline CORT elevations on reproductive phenology. Our results suggest that elevated baseline CORT prior to investment in reproduction has a direct positive impact on resource acquisition and play a strong mechanistic role in driving variation in key life history decisions via influences on foraging. Additionally, testing these mechanistic relationships will provide researchers with the predictive capacity to understand how physiology may affect adaptability of Arctic-breeding species, particularly those facing increasing climatic variability.

P3-94 HENNIN, HL*; DEY, CJ; BETY, J; GILCHRIST, HG; LEGAGNEUX, P; WILLIAMS, TD; LOVE, OP; University of Windsor, ON, Great Lakes Institute for Environmental Research, Windsor, ON, Université du Québec à Rimouski, QC, National Wildlife Research Centre, Ottawa, ON, Université du Québec à Rimouski, QC, Simon Fraser University, Burnaby, BC; *hollyhennin@gmail.com*

Pre-Breeding Fattening Mediates Investment in Clutch Size in a Capital-Income Breeding Seaduck

Many species experience a seasonal decline in clutch size, and theoretical models predict two possible, non-exclusive pathways influencing this relationship: 1) poor condition at arrival on the breeding grounds may delay laying and thereby reduce investment in the clutch, or 2) later arriving females may have reduced resource availability to support the formation of a large clutch. If lower condition or later-arriving females can gain in condition at a faster rate they may be able to lay larger than expected, earlier clutches. Lipid accumulation and management is critical prior to laying in common eiders (Somateria mollissima) which must accumulate significant fat stores prior to laying to both fuel follicle growth and deposit the fat stores needed to successfully complete their 24-day incubation fast. Here we use an 11-year data set collected from East Bay Island, NU, Canada, in pre-recruiting, Arctic-nesting female eiders to examine the effect that fattening rate may have on clutch size. We quantify fattening rate using plasma triglycerides (TRIG) and energetic metabolite. Path analyses revealed that fattening rate had an indirect effect on clutch size via a direct influence on the timing of laying: females with higher fattening rates (TRIG) laid earlier and produced larger clutch sizes. Our results are the first to provide mechanisms underlying the well-documented seasonal decline in clutch size across species, namely that fattening prior to breeding indirectly influences reproductive investment via changes to breeding phenology.

38-6 HENNINGSSON, P*; JAKOBSEN, L; HEDENSTRöM, A; Lund Univ., Sweden, Univ. of Southern Denmark, Denmark; *per.henningsson@biol.lu.se*

Aerodynamics of manoeuvring flight in bats

Research on animal aerodynamics to date has been largely limited to steady level forward flight. In recent years the techniques used in aerodynamic research have developed and the resolution of the aerodynamic tracks we are able to record and reconstruct has been greatly improved - both temporally and spatially. Therefore, it is now possible to analyse how animals execute manoeuvers through asymmetries in timing and magnitude of forces generated by the two wings dynamically through the wingbeat. In the daily life of any flying animal, manoeuvring is something that is ever present; predators pursuing prey, prey avoiding predator, coping with gusty winds, negotiating cluttered environments, and so on. For bats catching insect prey on the wing, the way they execute their manoeuvers is of direct importance to their biology and ecology. Here we present the results from the first ever study to explicitly explore the aerodynamics of manoeuvring flight in bats. We performed a set of experiments on Brown long-eared bats (Plecotus auritus) flying in a wind tunnel and used time-resolved stereo particle image velocimetry (PIV) to capture the wakes. We encouraged the bats to perform sideways manoeuvers by laterally translating a thin metal sting holding a mealworm at the instant just before the bat approached it. We identified three main phases for analysis; (i) initiation of the manoeuver, (ii) execution of the manoeuver, and (iii) termination of the manoeuver and stabilization and show that, depending on the timing of these events within the wingbeat cycle, the bats can use both upstroke and downstroke to generate the required force asymmetries.

P3-78 HENRY, M*; STONECIPHER, J; GOLDINA, A; Elizabethtown College; *henrym1@etown.edu*

Behavioral response to same-sex pheromones by the invasive crayfish Orconectes rusticus

Crayfish communicate chemically. The crayfish *Orconectes rusticus* is an invasive species that has taken over most watersheds in the country. Traditional eradication methods have not been successful. Understanding how *O. rusticus* respond to pheromones from different sources can be helpful in developing species-specific chemical traps. In this study we assessed how *O. rusticus* respond to chemical signals generated by conspecifics of different sexes. We constructed a Y-maze with each arm receiving different chemical signals. To ensure that individuals don't exhibit side bias, water was pumped through both arms. In the absence of a chemical signals in the water, individuals did not show preference for a particular arm of the maze. However, when a food signal was pumped through one of the arms, individuals consistently moved towards the arm containing the food signal ($n=16$, $p< 0.01$). We then created same-sex male and female pheromone solutions by combining water from 18 males and 20 females that have been isolated for 7 days. We assessed the minimum concentration of stock pheromones needed to elicit selective movement by the receiver. Male and female *O. rusticus* were exposed to 10%, 25%, and 50% same-sex pheromone stock that was pumped down one randomly chosen arm of the maze, while water was pumped through the other arm. Individuals were believed to make a choice when they moved towards or away from an arm containing the chemical signal. Our preliminary data show that at higher concentrations, males spent more time away from the same-sex pheromone, while females spent more time in the arm containing the chemical signal. These findings suggest that *O. rusticus* exhibit sexually dimorphic behavior strategies towards same-sex pheromones. These findings would be an important consideration when designing traps to limit invasion spread by *O. rusticus*.

57-1 HENRY, ER*; BUTLER, MB; University of Hawaii, Manoa; *erh@hawaii.edu*

Population Structure of Two Native Hawaiian Damselflies

We compared population structure of two native Hawaiian damselflies (Megalagrion nigrohamatum nigrolineatum and Megalagrion vagabundum) to study the effects of life history strategy on gene flow. The two subject species are good representatives of a habitat generalist (M. vagabundum) and an endangered damselfly that is restricted to dark pools along streams and behaviorally seems to be a poor disperser (M. n. nigrolineatum). They are a part of a highly diverse adaptive radiation of 23 damselflies, 6 of which are endangered, which have evolved different breeding site preferences. Microsatellite and COI-COII mitochondrial data showed small genetic differentiation among populations in both species. M. n. nigrolineatum showed evidence for isolation-by-distance indicating a limitation to dispersal based on geographic distance whereas a mountain ridge acted as a gene barrier in M. vagabundum. These results are discussed in view of life history differences, landscape differences, and conservation and management.

45-4 HENSCHEN, A.E.*; WHITTINGHAM, L.A.; DUNN, P.O.; Univ. of Wisconsin, Milwaukee; *hensche9@uwm.edu*
Resistance to oxidative stress mediates the acute stress response in common yellowthroats
Ornaments are thought to honestly signal individual quality to potential mates. Individual quality may include the ability to cope with stress through the production of glucocorticoids (GCs), which help to redirect resources from growth to survival. However, increases in GCs can also have negative physiological consequences, such as inducing oxidative stress due to the stimulatory effects GCs have on cellular respiration. Thus, an important question is whether high quality individuals, with more elaborate ornaments, can mitigate some of the negative effects of a strong stress response (i.e., a high increase in GCs) if they are more resistant to oxidative stress. We studied this question in the common yellowthroat (*Geothlypis trichas*). Male common yellowthroats have two sexually selected plumage ornaments, a melanin-based black mask and a carotenoid-based yellow bib. We measured the acute stress response as the increase in corticosterone (CORT), the main GC in birds, in response to the stress of handling. As predicted, we found that males with more elaborate ornaments (larger masks and bibs with more carotenoid chroma) had a greater increase in CORT during an acute stress response, and the increase was relatively greater if males also had stronger resistance to oxidative stress. These results suggest that individuals with the most attractive ornaments may be able to mitigate the physiological costs of an acute stress response by mounting a stronger response to oxidative stress.

P1-205 HENSLEY, VR*; LEVESQUE, DL; University of Maine, Orono, Maine, USA; *vanessa.hensley@maine.edu*
Squirrels on the move: The response of Southern flying squirrels (G. volans) to rising ambient temperatures
Increasing temperatures have the potential to rapidly alter species' range distributions and subsequent interactions. In North America, both species of flying squirrel (*Glaucomys volans* and *G. sabrinus*) have already undergone significant northward range shifts over the past 25 years. Previous studies point to higher winter temperatures as the driver and so, largely focused on the effects of cold temperatures on thermal physiology. We are interested in the other piece of the puzzle - the effects of high ambient temperatures on the thermophysiology of the only genus of nocturnal tree squirrels in North America. We measured resting metabolic rate and subcutaneous body temperature of southern flying squirrels, at the leading edge of their northern expansion, across a range of ambient temperatures, with a particular focus on temperatures above 30°C. We also measured free-ranging, core body temperature of southern flying squirrels and American red squirrels (*Tamiasciurus hudsonicus*) during late summer/early fall. Free-ranging, core temperature data is virtually non-existent for North American flying squirrels and can provide insight into the suite of thermoregulatory characteristics that may aid or hinder northward expansion. The diurnal American red squirrels occupy a similar ecological niche, but different temporal niche, as the nocturnal flying squirrels. The diurnal/nocturnal comparison between flying squirrels and red squirrels offers another opportunity for uncovering thermal physiological drivers of geographic distributions and range shifts in small mammals.

89-4 HENSON, JH*; SIMS, CG; SCHOECH, SJ; University of Memphis, University of Arkansas at Monticello; *jhenson2@cbu.edu*
Stress Physiology and Body Condition of Mallards (Anas platyrhynchos) Changes Across Fall and Winter
Waterfowl face a multitude of stressors across the fall and winter. These stressors include energetic demands associated with annual cycle stage, weather, habitat availability, and waterfowl hunting seasons. Stressful stimuli elicit a physiologic stress response culminating with the release of corticosterone (CORT). CORT aids in survival and recovery over the short-term, but if elevated over a long period it can lead to decrements in health. To avoid the potential harmful effects of prolonged elevations in CORT, some birds seasonally dampen their response to a predictable stressor. The aim of this study was to examine the changes in stress physiology and body condition of mallards (*Anas platyrhynchos*) across the fall and wintering period. Mallards were sampled via netting or lethal take pre-migration in North Dakota and across the fall and winter in eastern Arkansas. Netted mallards underwent a standard capture and handling protocol with blood samples taken over an hour, whereas shot mallards had a blood sample taken immediately. Blood samples were used for CORT analysis and a body condition index was assessed using morphometrics. Baseline CORT levels did not change across seasons, but body condition was reduced in mallards across the fall into winter, and was lowest during the hunting season. Mallards had a reduced CORT response during fall migration and an increased response during the late winter when mallards complete pair formation. These results are similar to other species in which there were no changes in baseline CORT across seasons; a dampened CORT response during the energetically expensive periods of migration and molt, and increased responsiveness associated with breeding behaviors.

P2-94 HENSON, KE*; CARTER, AJR; California State University, Long Beach; *katherineelizabethhenson@gmail.com*
Effect of Previous Exposure to a Female of a Single Phenotype on Subsequent Male Mate Choice in Drosophila melanogaster
A prevalent paradigm in sexual selection theory is Bateman's principle of a "choosy female" and "promiscuous male," leading to male mate choice being deemed inconsequential. However, male choice may play a larger role in sexual selection than previously thought. We examined male choice in *Drosophila melanogaster* by observing relative preference for certain phenotypes by males after differing initial exposure treatments. Virgin male wild type *D. melanogaster* individuals were exposed to a female that was wild type, yellow, or ebony. Later, the same males were allowed to choose between three females differing in phenotype: two thereby having novel phenotypes and one having the phenotype already encountered. Males showed a significant preference for novel phenotypes, with the familiar phenotype being the least preferred ($p=0.0175$). This evidence supports a process by which males aim to increase genetic diversity among offspring by mating with phenotypically diverse females when given the opportunity.

77-5 HEPPNER, JJ*; LANGKILDE, T; OWEN, DAS; SHERIFF, MJ; Pennsylvania State University, University Park; *jenniferheppner4@gmail.com*

Effects of Maternal Stress on Performance Behavior of Lizard Offspring

When faced with a stressor, animals mount a physiological stress response involving secretion of stress relevant hormones, including corticosterone (CORT). This response is fundamental to animals' ability to respond to predictable and unpredictable stressors and during pregnancy, can influence the phenotype, performance, and fitness of resulting offspring. The Environmental Match Hypothesis proposes that maternal stress will adaptively prepare offspring to cope with the environment experienced by the mother. There are few studies that have shown the effects of this maternal stress in offspring from wild caught females. We tested two hypotheses: 1) that maternal stress will alter fitness-relevant behavior of offspring expressed at one week and one month of age; 2) that acute stress will have stronger effects on the behavior of offspring from stressed mothers. We manipulated stress of gravid female Eastern Fence Lizards (*Sceloporus undulatus*) by dosing them daily with ecologically-relevant concentrations of CORT, to mimic those resulting from attack by fire ants (*Solenopsis invicta*). We measured sprint speed, righting ability, and response to tactile cues of ant attack of the resulting offspring close to hatching and at one month of age, and following application of CORT. We will present results on effects of maternal CORT-treatment on these ecologically-important performance measures. These results will reveal fitness-relevant consequences of maternal stress for offspring behavior, and will lead to a better understanding of how maternal stress may promote offspring survival in a stressful environment.

75-5 HERBST, E*; SMITHSON, TR; CLACK, JA; DOUBE, M; HUTCHINSON, JR; Royal Veterinary College, Univ. Museum of Zoology, Cambridge; *eherbst@rvc.ac.uk*

Bony Lesions in Early Tetrapods and the Evolution of Bone Healing

Some analyses of pathologies in the fossil record use these pathologies to infer specific behaviours or ecologies for extinct animals. This is problematic because different types of injuries and diseases can result in similar gross pathology. Instead, here we conducted a synthesis of the phylogenetic distribution of evidence for bone healing and regeneration in vertebrates (especially tetrapods) to reconstruct how these traits evolved. Where feasible, we also used μCT scanning to determine whether an unusual bony feature was pathological. This was especially relevant for animals with a fragmentary fossil record, because a lack of comparative specimens or small sample size makes it difficult to distinguish between normal osteological traits and pathological growths. We report new cases of pathological bone formation in the limb bones of two early tetrapods, *Crassigyrinus scoticus* and *Eoherpeton watsoni*, from the Carboniferous of Scotland. These features were initially interpreted as unique sites of muscle attachment, but our scans revealed the pathological nature of the trabecular and cortical bone arrangement. Comparison of the pathology in the aquatic *Crassigyrinus* with the previously reported pathology in the Carboniferous tetrapod *Ossinodus pueri* reveals that we cannot infer terrestrial behaviour from such pathologies. However, these pathologies nonetheless have a broader importance. Although different bone healing pathways exist in extant taxa (distinguished by the presence or absence of cell dedifferentiation), our preliminary analysis including evidence from the fossil record suggests that vertebrates evolved the ability to repair bone in response to injury early on, perhaps as an exaptation of the bone modelling abilities involved in normal bone growth.

109-2 HERAS, J*; CHAKRABORTY, M; EMERSON, JJ; GERMAN, DP; Univ. of California, Irvine; *herasj@uci.edu*

The monkeyface prickleback (Cebidichthys violaceus) genome and transcriptomes as a source for understanding digestion and metabolism in an herbivorous fish

We sequenced the genome of the herbivorous monkeyface prickleback (*Cebidichthys violaceus*) along with transcriptomes from nine tissues to gain insight into how this fish species thrives on an herbivorous diet in a heterogeneous intertidal habitat. The draft genome of *C. violaceus* was sequenced using Illumina and Pacific Biosciences sequencing technologies, with a size estimation of 656 Mb and 29,525 genes were identified via ab initio. With the nine tissue transcriptomes, we generated heatmaps of differentially expressed genes to locate genes associated with digestion and metabolism. With the transcriptome profiles of the liver, pyloric caeca, proximal and middle intestines of *C. violaceus*, we identified differentially expressed genes (DEG) that are associated with ketogenic metabolism, which represent the downstream pathways allowing this fish to utilize the short-chain fatty acids generated by microbial symbionts within their distal intestines. In addition, we identified four gene copies (haploid) of Bile salt-activating lipase (BAL) genes within the *C. violaceus* genome (most other fishes appear to only have two BAL gene copies), which coincides with elevated lipolytic activity in the guts of this fish. BAL orthologs (as well as other genes involved in digestion and metabolism) and gene copy numbers were identified in other teleost fishes to make stronger inferences about digestion and metabolism. Overall, the draft genome of *C. violaceus* will give us a better understanding of the evolutionary processes of dietary specialization and can lead to hypothesis formation regarding adaptations to intertidal habitats.

P1-218 HERMANN-SORENSEN, H.*; RUSCHER-HILL, B.; TENGLER, M.; BRYAN, A.; REICHMUTH, C.; THOMETZ, N.M.; University of California Santa Cruz, Alaska Department of Fish and Game, University of San Francisco; *hhermann@ucsc.edu*

Aerobic and Anaerobic Properties of Bearded Seal Locomotor Muscle

The physiological properties of skeletal muscle in marine mammals play a key role in defining species-specific limits to diving and foraging. Given the fundamental separation of air at the surface and prey at depth, marine mammals must store and efficiently use oxygen within skeletal muscles to fuel aerobic metabolism, as well as manage the build-up of anaerobic byproducts within locomotor muscles, while foraging. For many Arctic species, navigation beneath sea ice presents an additional challenge. In this preliminary study, we examined aerobic and anaerobic properties of locomotor skeletal muscle in an Arctic phocid, the bearded seal (*Erignathus barbatus*). Samples from the longissimus dorsi muscle (n=7) were taken from bearded seals harvested by subsistence hunters in Point Hope, Alaska. Samples were analyzed for both myoglobin content and non-bicarbonate buffering capacity. Our results show that bearded seal locomotor muscle has a comparatively low myoglobin content (4.09 ± 0.45 g Mb/100 g wet tissue), but high buffering capacity (96.66 ± 3.23 slykes), for a phocid seal. We suggest this unique muscle physiology may be an adaption to foraging under sea ice. These data provide insight into the foraging capacities of bearded seals and can be used to inform predictions as to the resilience or sensitivity of this species to changing conditions.

86-5 HERNANDEZ, AM*; FARRELL, BD; Harvard University; *ahernandez@g.harvard.edu*
The Claw's the Limit: Understanding the Importance of Different Beetle Tarsal Structures in Relation to Landing Attachment
With over 350,000 described species, beetles are some of the most successful organisms on the planet. While beetles inhabit a wide range of ecological niches, the majority of them spend their lives on plants. Therefore, movement across varied surfaces is an essential part of their existence. However, the dynamics of beetle locomotion tend to receive less experimental consideration. Previous research has demonstrated that beetles have evolved adaptions in tarsal morphology allowing for controlled movements, such as walking, across varied surfaces. However, the attachment mechanisms utilized in a less-controlled type of motion, like landing after flight, are far less studied. To begin addressing some of these questions, we observed beetles landing on multiple textured surfaces, while also manipulating different components of their tarsal attachment systems. In order to do this, the tarsal claws were clipped in testing groups, while the adhesive setae were manipulated in others. Convergent lady beetles (*Hippodamia convergens*) served as the main test subjects for this study. Small UV blacklights were used to spotlight the tested surfaces to stimulate flight towards the desired location and high-speed video was used to view the landings. Results were recorded as successful attachment if the beetle was able to land on a surface without falling off. Previous attachment studies have indicated that the tarsal claw is more suited to rough surfaces and the adhesive setae to smoother surfaces. Given these indications, one could hypothesize that the removal of the claw would impact landings on rougher surfaces only. However, initial results seem to indicate that the tarsal claw may hold a more important role in landing on wide range of surfaces.

P1-38 HERNANDEZ, AM*; SCHULTZ , DT; FRANCIS, WR; KOREN, S; SCHNITZLER, CE; MARTINDALE , MQ; HADDOCK, SHD ; RYAN, JF; Whitney Laboratory for Marine Bioscience, St. Augustine, FL, Monterey Bay Aquarium Research Institute, Moss Landing, CA, National Human Genome Research Institute, Bethesda, MD, Whitney Laboratory for Marine Bioscience, University of Florida; *ahernandez6@ufl.edu*
Not content with sequence alone: Independent evidence for the positions of ctenophores and sponges using expanded gene content
Resolving phylogenetic relationships during the early evolution of animals has remained challenging due to taxonomic representation and use of differing data types and methodologies. The central disagreement has been focused on the placement of ctenophores (comb jellies) and sponges in differing phylogenomic studies, i.e., ctenophores as the sister group to all other animals, or sponges as the sister group to all other animals. The placement of ctenophores as the sister group to all other animals complicates questions surrounding the origins of true epithelia, nervous systems, muscles, and guts. In this study, we attempt to resolve the early evolution of animals by analyzing gene content data with expanded taxon sampling using both maximum-likelihood and Bayesian approaches and applying hypothesis testing. Using these approaches, we provide a hypothesis for the relationship of ctenophores, sponges, and the rest of animals that is independent of sequence-based methods.

P1-230 HERNANDEZ, J*; VERNASCO, BJ; ESCALLÓN, C; BELDEN, LK; MOORE, IT; Virginia Tech; *jess228@vt.edu*
Sexually transmitted microbes as a potential cost of extra-pair activity in female tree swallows
Up until the advent of modern molecular techniques, most avian species were considered to be truly monogamous. We now know that social and genetic mating systems are often not the same. Many species that were previously thought to be truly monogamous have been found to have extra-pair young, thus exhibiting evidence for extra-pair reproductive activity. While females face numerous potential fitness benefits from mating with multiple males (e.g. good genes, genetic diversity in offspring), they also face costs (e.g. loss of paternal care, de novo deleterious mutations). Another potential cost of mating with multiple males is acquiring sexually transmitted diseases. In our study, we focused on the sexual transmission of pathogenic microbes, which has been suggested to be a cost of extra-pair activity to females since as early as the 1970s but has not yet been adequately tested. Previous research has identified and described the cloacal microbial communities of birds, however, how sexual activity affects, and is affected by, these communities in wild populations is largely unknown. We took cloacal swabs from adult female tree swallows (*Tachycineta bicolor*) and then determined the taxonomic composition and pathogenic load of the cloacal microbiome. We also determined paternity of the young as an estimate of the number of males each female had mated with. Through continued observational and future experimental studies, we hope to elucidate the relationship between extra-pair copulations and the presence, prevalence, and pathogenicity of sexually transmitted cloacal microbiota, with respect to fitness, in wild avian populations.

P3-266 HERNANDEZ, C*; WEINBERG, R.B.; COHEN, C.S.; San Francisco State University Department of Biology, Romberg Tiburon Center , San FranciscoState University Department of Biology, Romberg Tiburon Center; *ceciliah450@gmail.com*
COI haplotype diversity of three populations of the invasive colonial tunicate Didemnum vexillum in the Pacific Northwest
Didemnum vexillum is an invasive colonial tunicate which poses serious and ecological and economic threats to invaded regions due to its ability to overgrow and smother native sessile invertebrates, fish eggs, and commercially important aquaculture species. Assessing the genetic diversity of introduced *D. vexillum* populations in both isolated and well-connected regions can yield valuable insights into the connectivity between populations and aid our understanding of the introduction vectors and dispersal potential of this marine invader. This study examines the COI haplotype diversity in an isolated *D. vexillum* population in the Umpqua Triangle, Oregon (n=20), and two California populations with higher connectivity via small boat and gear traffic: Drakes Estero (n=7) and Bodega Bay (n=10). Partial mitochondrial COI sequences from 37 samples are analyzed to determine the haplotypic diversity of each of the three populations. Preliminary data confirms low haplotype diversity in the Bodega Bay population, which experiences recreational and small fishing boat traffic. Haplotypes found in invasive populations globally are also found in these and other northeast Pacific populations. t. Our findings agree with the genetic data gathered from other invasive *D. vexillum* populations, indicating that haplotype diversity is generally limited in introduced populations in comparison to the high levels of haplotype diversity found in the native region of Japan.

100-3 HERNDON, CJ*; FENTON, FH; Georgia Institute of Technology; *co.herndon@gmail.com*

Not all heartbreak is the same: a cross-species analysis of cardiac electrical instabilities

The transmembrane voltage and intracellular calcium dynamics in cardiac muscle varies greatly across species. Through the use of high spatiotemporal resolution optical mapping on Langendorff perfused hearts, we've analyzed the voltage and calcium dynamics in zebrafish, frogs, rabbits, rats, cats, dogs, pigs, ferrets, and alligators. I will focus my discussion on alternans, a pro-arrhythmic period doubling bifurcation in cardiac action potentials resulting from increasing rate of stimulation. Understanding the mechanisms underlying alternans is of great importance, as this dynamical instability provides an arrhythmic substrate for fibrillation and is strongly correlated with sudden cardiac death. In zebrafish hearts the onset of alternans is driven by the voltage dynamics in a pitchfork bifurcation, whereas alternans in rabbits and cats is driven by calcium dynamics in a border collision bifurcation, but although rabbits display voltage alternans, cats do not. Pigs and alligators do not develop alternans in either voltage or calcium, but alligators do not fibrillate. In this talk I will discuss more species and how the mechanisms underlying alternans can vary.

131-6 HERRERA, MJ*; HERAS, J; GERMAN, DP; University of California, Irvine; *mjherre1@uci.edu*

Digestive specialization in prickleback fishes (Family Stichaeidae): Liver Transcriptome and Metabolic Rate

Prickleback fishes (Family Stichaeidae) are a unique study system in which to investigate dietary specialization because they consist of closely related species that coexist in rocky intertidal habitats, yet vary in diet. Dietary habits affect the utilization of various metabolic pathways and the liver is central to many metabolic processes. Thus, my goal is to examine whether there are dietary-related metabolic differences between prickleback fishes by investigating metabolic rate and liver metabolic pathways in different species with different diets, and how flexible these pathways are in response to dietary changes. We studied four species that naturally vary in diet: *Xiphister mucosus* (herbivore), *Xiphister atropurpureus* (omnivore), *Phytichthys chirus* (omnivore), and *Anoplarchus purpurescens* (carnivore). We assigned individuals of *X. mucosus* and *A. purpurescens* to omnivore or carnivore diets in the laboratory, whereas *X. atropurpureus* and *P. chirus* individuals were fed the carnivore diet. In lab-fed fishes, the metabolic rate did not vary among the species, nor were any dietary-induced intra-specific differences in metabolic rates detected. The transcriptomic profiles of the liver tissues of wild-caught and lab-fed individuals were examined using Illumina platforms. We performed genome-driven transcriptomic assemblies with the prickleback *Cebidichthys violaceus* genome as the reference. Coverages of 15-21 million reads per sample were achieved and analyses of differential expression of genes involved in metabolic pathways are underway. Overall, this study will provide insight into the relationship between energy metabolism and diet in vertebrates, and how flexible these systems may be in the face of dietary shifts.

100-6 HESSEL, AL*; NISHIKAWA, KC; Northern Arizona University, Flagstaff, Arizona, USA; *alh385@nau.edu*

A role for titin in the activation-dependent shift of the force-length relationship in skeletal muscle.

Muscle function during submaximal activation is seldom studied, yet is more similar to in vivo muscle function than maximal activation. For skeletal muscle, the force-length relationship shifts to longer lengths in submaximal, compared to maximal, activation conditions. Length-dependent calcium effects, specifically an increase in calcium sensitivity with increasing sarcomere length, have historically been suggested as the cause of this shift in the force-length relationship. Recent evidence suggests that the titin protein may also play a role in activation-dependent muscle properties through a length-dependent structural re-arrangement of the thick filaments. To evaluate a possible role for titin in activation dependent properties, we studied muscles from mice carrying the muscular dystrophy with myositis *(mdm)* mutation, which have a small titin deletion in the I-band region. For *mdm* and wild type soleus and EDL muscles, we measured the force-length relationships during maximal (tetanus) and submaximal (twitch) activation. We then used skinned fibers to evaluate the length-dependence of calcium sensitivity(LDC). Our results demonstrate that in contrast to wild type muscles, which showed a shift to longer optimal lengths during twitch contractions, the force-length relationship displayed the same optimum length for twitch and tetanic contractions in *mdm* muscles. However, in skinned fibers, the length-dependence of calcium sensitivity was similar in *mdm* and wild type fibers. These results suggest that the titin deletion alters activation-dependent properties without affecting the LDC. Therefore, some mechanism other than LDC is responsible for the absence of an activation-dependent shift in the force-length relationship in *mdm* muscles. Uncovering how this titin deletion affects activation dependent properties will be the subject of future study.

P3-129 HEUERMANN, TM*; POLEKOFF, S; CURRY, RL; Villanova University; *theuerma@villanova.edu*

Variation in boldness and exploratory behavior as components of personality within and between black-capped and Carolina chickadees

Behavior that is consistent within individuals but variable across and between populations, or personality, may have important ecological and evolutionary implications. As part of our research program on hybridization between black-capped and Carolina chickadees in southeastern Pennsylvania, we seek to understand whether personality variation can influence the extent and patterns of interbreeding. In this study, we investigated patterns of variation in boldness and exploratory behavior both within and between the two species. We measured boldness of breeding pairs by their vocal and spatial responses to simulated predator threats at active nests. In addition to considerable intraspecific variation, Carolina chickadees gave more scolding calls with more dee notes (an indication of their perception of threat) but attacked decoys less vigorously than did black-capped pairs. To measure exploratory behavior, we observed individuals inside a portable aviary deployed at our field sites. Composite scores of exploratory behavior, calculated using principal components analysis, were highly repeatable within individuals while averaging higher for Carolina than black-capped chickadees. These results suggest that potential exists for personality variation to influence hybridization through effects on social interaction and mate choice in mixed populations. Work in progress asks whether personality correlates with intraspecific and interspecific variation in DRD4 genotypes.

P1-293 HIDALGO, F*; STINSON, CM; BERG, O; MÜLLER, UK; CSU, Fresno, CSU, Bakersfield; *hidalgof@mail.fresnostate.edu*
Comparing suction feeders: carnivorous plants versus paedomorphic salamanders
Suction feeding is a common feeding mode in aquatic organisms. So far, we have data on adult and larval fish, adult salamanders, tadpoles, and aquatic bladderworts. In this project, we focus on two understudied groups: paedomorphic salamanders and terrestrial bladderworts. Terrestrial and aquatic bladderworts differ in their mouth morphology, as do paedomorphic versus adult salamanders. We used the paedomorphic *Ambystoma sp.*, also known as axolotl. We used the terrestrial bladderwort species *Utricularia praelonga*, which has slit-shaped mouths, unlike the aquatic species *U. vulgaris*. For this study, we compared the flow (such as maximum flow speed) and the movement patterns (such as maximum gape, time to maximum gape) across species. We found that paedomorphic salamanders are similar to fish and adult salamanders in their performance and that terrestrial bladderwort are similar to aquatic bladderworts, despite considerable differences in mouth morphology. Axolotl time to peak gape and gape is similar to adult fish and adult salamanders (order of magnitude of 10^2 to 10^3 ms; 10^1 to 10^2 mm); bladderworts have much smaller times to peak gape and gape diameters (order of magnitude 10^{-1} ms, 10^{-1} mm) than adult fish and salamanders, and similar gapes but much smaller time to peak gape than larval fish (10^{-1} mm, 10^1 ms). Bladderwort peak flow speeds (10^1 m/s near the mouth) are more similar to adult fish (10^{-1} to 10^1 m/s) than larval fish and paedomorphic salamanders (10^{-3} to 10^{-2} m/s). Gape size is not a strong predictor of suction kinematics and flow; small suction feeders can generate similar suction flows to adult fish and large, aquatic salamanders.

5-3 HIERONYMUS, T*; WAUGH, DA; BALL, H; COOPER, LN; NEOMED; *thieronymus@neomed.edu*
Balancing Structure & Materials: Torsion-Resistant Collagen Organization in the Wing Bones of Birds and Bats
The mechanical strength of bones is influenced both by their shape and by collagen fiber orientation (CFO) within the bone matrix. Birds and bats have independently evolved wing bones that are thin-walled and circular in cross-section, a shape that maximizes resistance to torsional stress for a given bone area. Variability in CFO presents a mechanism for tissue-level optimization of stiffness. We tested whether bird and bat forelimbs displayed CFO better aligned to resist torsion than non-volant outgroups using quantitative polarized light microscopy (qPLM) with a novel set of image analysis functions for the R statistical package. Mid-cortical bone of both volant and non-volant taxa showed similar distributions of longitudinal CFO. In agreement with prior work, we found that bats and birds display a distinct region of endosteal bone along the medullary cavity with more transverse CFO. Our results show that endosteal bone is composed of single-sense helically-oriented collagen fibers at ~45º pitch, a near optimal arrangement for resisting torsion. Endosteal bone displayed evidence of remodeling, whereas the mid-cortical region was most often composed of primary bone. Simple biomechanical models of strain in torsion show that despite its location closer to the cross-section centroid, endosteal bone is expected to make a major contribution to torsional stiffness. We propose that the endosteal rim of helically-oriented bone represents a compromise between tissue-level adaptation to torsional loading and the structural consequences of bone remodeling—while the endosteal position is not structurally ideal for torsion resistance, it is structurally the 'safest' and most accessible place from which to remove fatigue-damaged bone from the thin cortices of bird and bat long bones during remodeling.

78-5 HIGGINS, B/A*; LAW, C/J; MEHTA, R/S; Univ. of California, Santa Cruz; *bahiggin@ucsc.edu*
Functional Ecology of the California Moray Eel (Gymnothorax mordax): Dietary Breadth and Bite Force Over Ontogeny.
Despite the growing body of data on predatory interactions, we are still lacking information on the feeding ecology for many top predators that inhabit kelp forest ecosystems. The elusiveness of some large predators contributes to the paucity of information. For six years, we have been gathering data on the cryptic California moray eel (Gymnothorax mordax). Here, we present dietary breadth and bite force data for morays inhabiting Two Harbors, Santa Catalina Island, CA. Morphological data and dietary items were recovered from sedated morays using manual palpation. Dietary items were measured and classified to the lowest distinguishable taxonomic unit. In vivo bite force measurements were collected on 49 morays ranging from 567 - 1192 mm total length. Between 2012 and 2016, the main dietary items of morays consisted of kelp bass, octopus, and red rock shrimp, respectively. Kelp bass (80 - 297 mm total length) was the most consumed item across all sites and years, suggesting that morays may be imposing a significant source of predation pressure on juvenile and recruiting kelp bass. Bite forces ranged from 32 - 467 N; bite force exhibited positive allometry with moray head length and width. Our prey size data indicate that as morays grow larger, they are capable of consuming larger prey, but smaller items still remain in the diet. Additional analyses using prey availability and abundance data suggest that morays are generalist predators, consuming a wide range of prey. Our results indicate that morays may be highly influential piscivorous predators in the Southern California kelp forest ecosystem, frequently preying upon a kelp bass - a species also known to impact a wide range of vertebrate and invertebrate prey.

86-3 HIGHAM, T.E.*; RöDDER, D; THIELEN, M; SPECK, T; Univ. of California, Riverside, Museum Koenig, Univ. Freiburg, Univ. Freiburg; *thigham@ucr.edu*
Comparative adhesive capacity and morphology of day geckos (Phelsuma) in relation to native plant surface microstructure
Geckos adhere to natural surfaces via the close interaction of setae and the intricacies of the substrate. Although considerable attention has focused on the adhesive microstructure and force generation of geckos, few studies have actually considered the natural surfaces on which they move. Recent work examining the interaction between geckos and rock surfaces, for example, revealed that the area available for contact is very limited in certain situations, thereby diminishing the frictional adhesive force. Many arboreal geckos are noted to move on smooth plant surfaces, including leaves and smooth tree trunks. Therefore, we examined the setal microtopgraphy of approximately 20 species of *Phelsuma* from museum collections using SEM, and then examined the 3D microtopography of the plant surfaces on which they have been observed using in nature and in semi-natural enclosures. In addition to the fresh plant surfaces, we created replicas to mimic the variation in surface roughness, which increases due to epicuticular wax crystals, trichomes, and cuticular folds. We determined the theoretical contact area, in addition to a number of morphological traits of the plant and gecko surfaces. We predicted that the real contact area between the gecko adhesive apparatus and the surface is reduced by certain surface microstructuring, but may be enhanced by others. We then obtained several species of live *Phelsuma* and used the replicas and a sensitive tensile load cell to test the frictional adhesive force capability. Finally, we quantified locomotor ability on trackways constructed from the replicas of plant surfaces.

38-5 HIGHTOWER, BJ*; WIJNINGS, P; INGERSOLL, R; CHIN, DD; SCHOLTE, R; LENTINK, D; Stanford University, Sorama & University of Einghoven, Sorama; *bhightow@stanford.edu*

How Hummingbirds Hum: Acoustic Holography of Hummingbirds During Maneuvering Flight

Hummingbirds make a characteristic humming sound when they flap their wings. The physics and the biological significance of hummingbird aeroacoustics is still poorly understood. We used acoustic holography and high-speed cameras to determine the acoustic field of six hummingbirds while they either hovered stationary in front of a flower or maneuvered to track flower motion. We used a robotic flower that oscillated either laterally or longitudinally with a linear combination of 20 different frequencies between 0.2 and 20 Hz, a range that encompasses natural flower vibration frequencies in wind. We used high-speed marker tracking to dissect the transfer function between the moving flower, the head, and body of the bird. We also positioned four acoustic arrays equipped with 2176 microphones total above, below, and in front of the hummingbird. Acoustic data from the microphones were back-propagated to planes adjacent to the hummingbird to create the first real-time holograms of the pressure field a hummingbird generates *in vivo*. Integration of all this data offers insight into how hummingbirds modulate the acoustic field during hovering and maneuvering flight.

50-1 HILL, AL*; HALL, C; RIVERA, A; POSFAI, D; RODRIGUEZ, M; GARCIA, J; HILL, April; Univ. of Richmond, Virginia, Univ. of Virginia, Univ. of the Pacific, Stockton, California, Duke Univ., Durham, North Carolina; *ahill2@richmond.edu*

Patterning the freshwater sponge aquiferous system: Wnt signaling and Pax networks

Canonical and non-canonical Wnt signaling, as well as the Pax/Six gene network, are involved in pattering of the freshwater sponge aquiferous system. Here, we describe a regulatory connection between the demosponge Pax transcription factor and components of the Wnt signaling pathway, suggesting that regulation of Wnt signaling by Pax family members may predate the divergence of sponges. We also functionally demonstrate a further role for Wnt signaling in aquiferous system development, showing that a Secreted Frizzled Related Protein (SFRP) likely acts as a Wnt antagonist. Finally, we find that SFRP localizes to a subpopulation of mesenchymal stem cells (archeocytes with filipodia) in the sponge mesohyl and suggest a role for SFRP in initiating morphogenetic processes.

P3-91 HINES, SM*; SHUMAN-GOODIER, M; SINGLETON, G; PROPPER, C; Mohave Community College, Lake Havasu City, Northern Arizona Univ., Flagstaff, International Rice Research Institute, Phillipines; *crazyloudparty12@gmail.com*

Exposure to the herbicide, butachlor, affects development of the thyroid gland in R. marina tadpoles

Exposure to herbicides may influence development through disruption of endocrine processes. Butachlor is an herbicide used commonly in rice agriculture that influences thyroid hormone function. To better understand the potential consequences of butachlor exposure, we examined the effect of butachlor on development of the thyroid gland in cane toad tadpoles, *Rhinella marina*. Eggs, tadpoles, or eggs and tadpoles were exposed to 0, 0.002, 0.02, and 0.2 mg/L butachlor, and thyroid gland histology was evaluated via imaging to determine a total follicle count, follicle and colloid area, and thyrocyte height and width. Butachlor decreased the number of thyroid follicles in animals exposed at any life stage; however, exposure only influenced thyrocyte width and height at the lowest dose in animals exposed at the egg stage. Butachlor exposure had no effect on thyroid follicle size. Our results suggest that butachlor affects thyroid gland development without influencing shifts in follicular morphology. Future studies should measure thyroid hormone levels in butachlor exposed tadpoles.

2-5 HODGE, JR*; WAINWRIGHT, PC; Univ. of California, Davis; *jhodge@ucdavis.edu*

Sociality and Foraging Strategy Interact to Affect the Evolution of Defensive Morphology

Evolutionary arms races between predator and prey drive the evolution of life. These races do not occur in isolation, but involve complex interactions between organisms, and with their environments that shape the outcomes. Understanding how these interactions constrain or promote adaptive evolution is a fundamental problem in biology. In teleost fishes, body shape and spine length have evolved synergistically to overcome the gape-limitation of predators. Here we reveal a breakdown of this evolutionary synergy in an iconic group of coral reef fishes. Our phylogenetically informed analyses show that deep-body shapes are highly conserved, while spine lengths and other defensive traits have evolved adaptively in relation to foraging strategy. Species that obligately graze on corals have reduced defensive morphologies, suggesting environmental constraint and a reliance on protection from corals. Moreover, we show that transitions to solitary behavior result in consistent shifts to more robust defenses. The shift is most pronounced in benthic hunters, highlighting the higher risk of predation faced by species with this foraging strategy.

54-5 HODIN, J*; FERNER, MC; NG, G; GAYLORD, B; Friday Harbor Labs, U. of Washington, USA, Romburg Tiburon Center and SFSU, CA, USA, Bodega Marine Lab, UC Davis, CA, USA, Bodega Marine Lab, UC Davis, CA, USA; *larvador@uw.edu*

Desperately Seeking Shoreline: Brief turbulence exposure induces echinoderm larvae to settle on lower quality substrates

The typical benthic marine organism releases its propagules for a minutes- to months-long dispersal stage before they settle again onto the seafloor. In those animals with a relatively lengthy dispersal period (weeks or more), the primary dispersing form is a feeding larva whose time in the plankton can be divided into three phases:
1) immature larva, physically incapable of transforming to the juvenile stage;
2) pre-competent larva, mature but non-responsive to settlement inducers; and
3) competent larva, that will settle when exposed to local settlement inducers, such as a bacterial biofilm or seawater containing cue from conspecifics.
An additional level of complexity can arise during the competent phase. Some larvae follow a 'death before dishonor' strategy: such larvae will never settle unless they receive a high quality indicator of suitable juvenile habitat. At the other extreme is so called 'desperate larvae', that will accept increasingly inferior settlement conditions as the competence phase proceeds. In previous work, we showed that brief exposure of pre-competent sea urchin and sand dollar larvae to intense fluid turbulence characteristic of waves breaking on the shoreline causes them to become competent to settle. Here we show that such turbulence exposure in competent larvae modulates their level of larval 'desperation.' Specifically, competent Pacific sand dollar larvae (*Dendraster excentricus*) settle more rapidly and into lower quality substrates if they have first been exposed to fluid turbulence. We observed a similar response in the Daisy brittle star, *Ophiopholis aculeata*. These results add to our growing understanding of how larvae use environmental information to modulate key life history decisions.

P2-233 HODSON-TOLE, E*; WAKELING, J; Manchester Metropolitan University, UK, Simon Fraser University, Canada; *e.tole@mmu.ac.uk*

Complexity of Myoelectric Signals is Influenced by Mechanical Demands of Locomotion

The control process underlying a signal can be quantified by assessing features of variability using measures like Sample Entropy (SampEn). Evaluating the time scale at which transition between SampEn values reflecting order to those reflecting randomness occurs within a signal can quantify short-term fluctuations that describe adjustments in the underlying signal process and are applicable to studying neuromuscular function during motor tasks. Here we investigate whether changes in features of myoelectric signal structure occur in response to altered locomotor demand. Myoelectric signals were recorded from three ankle extensor muscles of rats running on a treadmill at nine velocity/incline combinations. Standardised total intensity time series of recorded signals were reshaped to provide increasingly larger time intervals between consecutive data points prior to SampEn calculation. The time scale at which SampEn transitioned from structured to random (Entropic Half Life, EnHL) quantified the time scale over which structure within the signal persisted. To ensure results reflected structure within recorded signals EnHL values were also determined for phase randomised surrogate signals. A significant effect of locomotor velocity on EnHL values occurred in each muscle. The longest EnHLs occurred at the fastest velocities. Incline also had a significant effect. The shortest EnHLs occurred for locomotion on 0^{o} incline. EnHL values were significantly different between original and phase randomised signals indicating that phase related structure within them (i.e. the position of each of the data points in time) underpinned the EnHLs. Therefore, changes in EnHL reflect changes in underlying structure of recorded myoelectric signals. EnHL could have significant value as a novel marker of neuromuscular responses to changes in demand and intensity of a given motor task.

115-4 HOFFMAN, AH*; FINGER, JW; WADA, H; Auburn University; *ajh0077@auburn.edu*

The Effects of Developmental Stress on Future and Transgenerational Stress Tolerance

Developmental stressors are thought to have a negative impact on physiological functions and fitness. However, recent work suggests that a mild developmental stressor can have beneficial effects by increasing tolerance to the stressor later in life. The environment experienced by the parental generation can also affect offspring phenotype prior to fertilization or through parental effects. Adaptive transgenerational plasticity has been well documented in invertebrates, however less is known in the vertebrate taxa. We hypothesized that acquired stress tolerance decreases the negative effects of heat stress on fitness-related traits, and that this effect carries on into the next generation. To test this we conditioned juvenile zebra finches (*Taeniopygia guttata*) to a mild heat stress (38° C) or control temperature for 28 days. Later after reaching adulthood, the female birds were then exposed to a high heat stress (42° C) or control temperature for 3 consecutive days and then paired. The eggs of those females were then collected and incubated at a control or high temperature, and embryonic heart rates were measured at two time points [embryonic day 4 & 10/11] during development. Hatchlings were later euthanized to quantify organ mass. We predict that embryos from heat conditioned, heat stressed mothers will have heart rates in the high heat incubator comparable to embryos from control-control mothers that were in the control incubator. We also predict that hatchlings from heat conditioned, heat stressed mothers in the high heat incubator will have heart, yolk, and body masses comparable to hatchlings from control-control mothers in the control incubator. We will discuss the results in relation to developmental plasticity and potential mechanisms.

49-6 HOFFMANN, SL*; PORTER, ME; Florida Atlantic University; *shoffmann2014@fau.edu*

Asynchronous pectoral fin rotation during yaw turns in the bonnethead shark, Sphyrna tiburo

The agility of shark maneuvering is often referred to but remains understudied, likely due to challenges associated with calibrating large volume environments for 3D analyses. Studies documenting yaw maneuvering in the horizontal plane (2D) note asynchronous pectoral fin movements during turns in bonnethead sharks and Pacific spiny dogfish, but lack 3D fin kinematics. Previously, we adapted marker-based Video Reconstruction of Moving Morphology (VROMM) for use with two fully submerged cameras in a large volume environment (greater than 1m3) and found that Pacific spiny dogfish predictably protract, supinate, and depress their pectoral fin inside to body curvature while yaw turning. The goals of this study were to further innovated VROMM methods by: 1) expanding the calibrated volume of interest and 2) examining the 3D kinematics of both pectoral fins in the context of maneuvering kinematics during turning. We predict both pectoral fins will rotate with three degrees of freedom, and the inside fin is protracted, supinated, and depressed whereas the outside fin is elevated and retracted. Three Go-Pro Hero5 cameras were fully submerged at a depth of 1.5m with overlapping fields of view. Bonnethead sharks (Sphyrna tiburo) were outfitted with hemi-spherical black bead markers and enticed to maneuver in the filming volume (approximately 3.5m3). The movements of the fin and body were tracked in 3D and reconstructed. We found that bonnethead sharks rotate their pectoral fins in three planes during yaw turns. In all trials, the inside pectoral fin was supinated up to 28o; however, rotation in the other two planes were less consistent. By demonstrating consistently low errors with increasing filming volumes, we propose that development of this technique will lead to precise 3D analyses of larger animals and wild behaviors in the field.

131-2 HOLDEN, KG*; SPARKMAN, AM; MILLER, DA; BRONIKOWSKI, AM; Iowa State University, Westmont College, Pennsylvania State University; *pettinkg@iastate.edu*

Seasonal variation in baseline and stress-induced physiology in the western terrestrial garter snake (Thamnophis elegans)

Physiology facilitates the interaction between the environment and organismal fitness; thus, individual endocrine stress responses are likely to be fundamentally important for population-level responses to seasonal or environmental change. Glucocorticoids mediate trade-offs among energetic allocations and maintain homeostasis in response to stressors while also modulating day-to-day functions including feeding, locomotor activity, energy metabolism, and immune function. While glucocorticoids, such as corticosterone, are often assayed to evaluate the physiological response to stress by the hypothalamic-pituitary-interrenal (HPI) axis, other biomarkers of stress, such as circulating levels of blood glucose, provide additional measures by which we can quantify organismal responses to environmental variation. Here we use natural populations of the western terrestrial garter snake (*Thamnophis elegans*) representing two ecotypes from the Sierra Nevada Mountain range, near Eagle Lake CA, to quantify plasma levels of both baseline and stress-induced corticosterone and glucose across this species' active season. The populations that represent these ecotypes are part of a long-term study system that provides an ideal natural laboratory to test for the effects of seasonality on both individual and population level stress responses. We found that baseline and stress-induced physiological measures differed between ecotypes and across the active season.

117-2 HOLLIDAY, CM*; COST, IN; SELLERS, KC; MIDDLETON, KM; University of Missouri; *hollidayca@missouri.edu*

Using Ternary Plots to Convey 3D Jaw Muscle Orientation in Space and Time

Morphologists have long been challenged by presenting complex, 3-dimensional information in classical 2-dimensional projections for analysis and dissemination. Recent advances in capturing 3D data from the cranial or appendicular musculoskeletal system have certainly revolutionized the field, but we still are often relegated to presenting multiple, semi-redundant projections of jaw or limb muscle vectors in multiple planes of view, challenging readers' translational aptitudes. Conventionally, the third dimension is just ignored, often when calculating simplified lever metrics of vertical bite force or ground reaction force for example, where mediolateral components of the system are considered negligible. But this lost component is critical to understanding numerous biomechanical and evolutionary patterns, particularly in the evolution of wide-skulled reptiles including lizards, crocodilians and dinosaurs. Significant changes in skull shape, in all 3 dimensions, can occur during individual feeding bouts involving significant cranial kinesis, during ontogenetic changes in skull shape, such as in the crocodilians, or across evolutionary time during the origins of modern birds and crocodylians. Here we show how projecting 3D vectors of jaw muscles in a ternary, or triangle plot conveys changes in muscle orientation and force across different passages of time and across different individuals and taxa and enables us to better understand patterns and processes of feeding behavior, ontogenetic shape change and morphological evolution. We are employing this approach to visualize archosaur and reptile jaw musculature, however its applications extend to most other parts of the musculoskeletal system.

S2-1 HOLT, Natalie C*; WILLIAMS, C Dave; Northern Arizona University, University of Washington/ Allen Institute for Cell Science; *Natalie.Holt@nau.edu*

Compliance shifts the length-tension relationship in skeletal muscle

The relationship between length and tension (LT curve) observed in skeletal muscle is attributed to the requirement for overlap between actin and myosin. However, the LT curve varies with contractile conditions; optimum length is inversely correlated with activation level. We previously suggested that this is a consequence of compliance in series with actin and myosin during force transmission. Here we test this hypothesis by artificially varying the series compliance of the frog sartorius muscle, and show that optimum muscle length decreases with increasing series compliance. We suggest that the fiber shortening that occurs, even in nominally isometric contractions, in the presence of series compliance may be responsible for the decrease in optimum length. Shortening induced force depression is well established in skeletal muscle. The molecular mechanism underlying this phenomena is unknown. However, one current theory is that the internal strain induced by force production reduces the probability of myosin binding. This would prevent the formation of new crossbridges, and development of additional force, at the post-shortening length. This phenomena is likely to be length dependent, decreasing in effect size with decreasing length, and so may explain the shift towards shorter optimum length with increased series compliance and fiber shortening. We have developed a refined spatial model of the half sarcomere in which tropomyosin strain due to force production inhibits crossbridge binding. We use this to explore the combined hypothesis that shortening induced force depression is a result of strain-mediated crossbridge inhibition, and is responsible for the decrease in optimum length with increasing series compliance.

S9-6 HOOD, WR*; ZHANG, Y; MOWRY , AV; HYATT, HW; KAVAZIS, AN; Auburn Univ.; *wrhood@auburn.edu*

Re-evaluating life history trade-offs within the context of mitochondrial hormesis

The notion that reproduction has an effect on future performance and longevity is long-standing dogma in evolutionary biology, yet there is little understanding of the mechanisms that underlie this relationship. One variable that has emerged as a likely link between reproductive effort and longevity is oxidative stress. Specifically, it is has been proposed that reproduction increases oxidative stress and in turn, oxidative stress results in cumulating cellular damage that impacts an individual's longevity. Support for this hypothesis has been limited. We propose that there is limited support because ROS (reactive oxygen species), the molecules implicated in oxidative damage, are not consistently harmful. Instead, cells display a hormetic response to ROS exposure. For this presentation, the results of multiple studies that characterize how the mitochondria respond to an induced oxidative event and to a reproduction event will be described. In addition, how ROS exposure prior to reproduction impacts reproductive performance and how prior reproduction impacts a female's response to an induced oxidative event will also be presented. Cumulatively, these data suggest that, at least relatively early in an animal's reproductive life, increased ROS exposure associated with reproduction is more likely to enhance than to hinder the performance of females. Based on this evidence, we will propose a new model for understanding the tradeoff between reproduction and longevity whereby the early benefits of reproduction act to maximize subsequent reproductive performance, but delayed consequences of prior oxidative damage could contribute to early senescence in animals with high reproductive output. We recommend that future studies be designed to test these interacting effects.

53-1 HOOPER, AW*; BERGER, RW; CROCKER, DE; Sonoma State University, CA, Point Blue Conservation Science, Petaluma, CA; *hoopera@sonoma.edu*

Effects of maternal age on offspring behavior and growth efficiency in northern elephant seals (Mirounga angustirostris)

Offspring of capital breeders, such as the northern elephant seal (*rounga angustirostris*), are nursed exclusively from maternal body reserves. Previous investigations have shown that milk energy delivery rate in northern elephant seals increases with the size and age of the female. Milk energy intake and offspring storage data (n=47) suggests impacts of maternal age on growth efficiency that are independent of rates of energy delivery. To better understand the mechanisms underlying this effect of maternal age, behavioral data were collected from pups of 46 known-age females, from parturition to weaning, across six years and three different sites along the Central California Coast, representing 3954 seal-hours of observation. Pup behaviors were divided into five mutually exclusive categories that reflected pup energetics (e.g. locomotion vs. suckling). Maternal age had a significant effect on pup behavior. Pups of older females spent more time suckling and resting, while pups of younger females spent more time vocalizing, locomoting, or distant from their mother. Pup behavior also varied strongly with days post-partum and time of day. The magnitude of these effects varied between rookeries, suggesting influences of harem topography and environmental features on pup behavior. Together these finding suggest direct impacts of maternal breeding experience on pup behavior and growth efficiency.

P2-21 HOOPMAN, AR; NORTH, HA*; RAJAMOHAN, A; BOWSHER, JH; North Dakota State University, Fargo, USDA-ARS, Fargo; *Heather.ann@ndsu.edu*

Toxicity Assesment of Glyphosate on Honey Bee (Apis Meliffera) Spermatozoa

In 2016-2017, 33.2% of managed honey bee colonies in the U.S. were lost due to Colony Collapse Disorder (CCD). Commonly used pesticides are among the suspected reasons for bee mortality. N-(phosphonomethyl)glycine (glyphosate) is a widely used herbicide in the U.S. and has previously been shown to have behavioral effects on worker honey bees. However, effects of pesticides on honey bee reproductive physiology is understudied, especially with respect to the drone (male) bee. The queen bee receives semen from multiple drones just once during her life and stores the spermatozoa for 2-7 years. Even small amounts of pesticide tainted spermatozoa has the potential to affect the queen's fertility for the duration of her life. The purpose of this study was to assess toxicity of glyphosate to honey bee spermatozoa by determining the lethal dose (LD_{50}) and lethal time (LT_{50}). Previous studies elsewhere report that the nectar in a plant sprayed with glyphosate can contain between 0.002-0.0032 mg/ml of the herbicide. Sperm samples were collected from drones returning from the mating flight and treated with glyphosate dissolved in dimethyl sulfoxide (DMSO) to determine the lethal dose and time (LD_{50} and LT_{50}), respectively. After exposure, sperm samples were subjected to motility and live/dead assays. Preliminary results of this study support the hypothesis that glyphosate negatively affects honey bee spermatozoa. At 40 minutes of exposure time, the LD_{50} concentration was found to be 0.31mg/mL ($p<0.0001$). At 0.05mg/mL concentration of glyphosate in the semen, the LT_{50} was found to be 468 minutes ($p=0.009$).

27-5 HOPE, SF*; KENNAMER, RA; VAN MONTFRANS, SG; HOPKINS, WA; Virginia Tech, University of Georgia, William Fleming High School, Roanoke, VA; *shope@vt.edu*

Incubation Temperature and Social Context Affect Nest Exodus Performance of Precocial Ducklings

The environment that animals experience during development can have major fitness consequences. In birds, parents influence the developmental environment of their offspring through incubation. Subtle changes in incubation temperature affect offspring morphology and physiology, yet, little is known about how it may affect critical performance metrics. Further, performance is influenced by behavior, which can be affected by the social environment. We investigated whether incubation temperature and social context influence a critical early-life performance task in wood ducks. Wood ducks nest in tree cavities and, shortly after hatching, ducklings must jump and climb out of the cavity. Failure to do so in the wild is fatal. We incubated eggs at different temperatures and examined whether incubation temperature influenced the number of jumps, climbs, and the exit success of ducklings tested individually and in mixed-incubation temperature pairs. When tested individually, ducklings incubated at 35°C were 57% less successful at exiting the nest, and jumped and climbed less often, than those incubated at 35.8°C. However, social context mitigated these effects and there was no difference in exit success or associated behaviors when ducklings were tested in pairs. Further, after one duckling in the pair exited the nest, the remaining duckling jumped and climbed more often, suggesting that social interactions increased motivation. This demonstrates that offspring performance and behavior are affected by incubation temperature, which is especially important because human-induced environmental changes can affect parental incubation behavior. However, in some cases, social interactions may mitigate these negative effects.

P3-47 HOPPER, LM*; DUNCHEON, EJ; ALLEN, HC; CHAMPAGNE, AM; University of Southern Indiana, The Ohio State University; *lmhopper@eagles.usi.edu*

Patterns of Cutaneous Water Loss and Stratum Corneum Lipid Interactions During the Development of Japanese Quail

The development of regulatory mechanisms that prevent water loss is critical to survival in terrestrial organisms. In birds, over half of half water loss occurs through the skin as cutaneous water loss (CWL). As birds develop from hatchlings to adults, their ability to regulate CWL may be affected by ontogenetic, evolutionary, or environmental factors. The primary barrier to CWL is the SC, the outermost layer of the epidermis, composed of corneocytes surrounded by a matrix of lipids. The ability of these lipids to pack together and interact with water molecules may influence the rate of CWL. In this study, we hatched Japanese Quail (*Coturnix japonica*) and measured CWL every 2 days for 14 days. After isolating the SC, we used infrared spectroscopy to investigate lipid packing structure and hydrogen bonding in SC samples. Our results indicate that CWL is constant during development in Japanese Quail, results that differ from similar developmental studies in House Sparrows (*Passer domesticus*). This difference may reflect the environmental and ontogenetic differences associated with precocial development compared with altricial development. Additionally, we find that properties of hydrogen bonding and lipid packing throughout the developmental trajectory of quail underlie patterns of CWL.

P3-117 HORR, DM*; PAYNE, AA; JOHNSON, MA; Trinity University; *dhorr@trinity.edu*
Sex-Specific Effects of Temperature and Social Behavior on the Dynamic Body Color of the Green Anole Lizard
Color change in diverse animal species serves many ecological functions, including social signaling, camouflage, and thermal regulation. The green anole lizard, *Anolis carolinensis*, is one species that exhibits physiological color change, rapidly changing between bright green and dark brown in response to both external environmental cues and social stimuli. In this study, we tested whether there are sex differences in the relationships between body color and temperature, and body color and social behavior. We first examined how anole body color change may be influenced by thermoregulation on different types of substrates. We conducted field work on anole populations near San Antonio, Texas, where we noted lizard behavior, body color, and substrate type. We then captured each lizard, and immediately measured internal body temperature and body size. Our results demonstrate no relationship between body temperature and body color for either sex, suggesting that thermoregulation is likely not a primary reason for color change. We also used field observational data to assess whether the rate of social display behaviors is associated with the rate of body color changes, and the proportion of time the lizards were green. Overall, males were more likely to be green than females, and males changed their body color more frequently during social interactions. Our findings demonstrate the importance of dynamic body color in green anole ecology, and the differing roles that color may play between sexes.

80-7 HOSEK, KE*; ZIPPAY, ML; Sonoma State University; *hosek@sonoma.edu*
Under Pressure: The Physiological Response of Mytilus edulis to Multiple Stressors
The degradation of coastal marine ecosystems from anthropogenic climate change and a global dependence on ocean resources necessitates an understanding of how marine organisms are likely to be affected. Predictions about organismal response to climate change may not be reliable until we investigate under environmentally relevant settings that integrate both physical conditions and ecological aspects such as species interactions. This project explores the interactive effects of abiotic (temperature) and biotic (feeding history and risk of predation) stressors on intertidal mussels *Mytilus edulis*. We examined how the combination of multiple stressors affects biochemical processes at a subcellular level. Mussels from two feeding groups (starved and fed) were exposed to the presence or absence of predator cues at five water temperatures (ranging between 15-31°) across four short-term time points (between 0-60 min) to examine their physiological performance under acute stress events. Attention to the metabolic pathways that are independently and interactively affected by these stressors is key to understanding their role in shaping the whole-organism energetics of this important ecosystem engineer. To expound the effects of these stressors on metabolic functions, I will be measuring various enzymatic activity levels including citrate synthase to assess maximum aerobic capacity and lactate dehydrogenase to measure anaerobic reliance. We will also evaluate susceptibility to oxidative stress by measuring markers of oxidative damage and antioxidant capacity by measuring enzymatic activity of superoxide dismutase and catalase. This experiment will elucidate if a combination of stressors has a synergistic effect on biochemical processes and will provide critical insight into how environmental change may impact intertidal communities.

84-6 HOTALING, S*; GIERSCH, JJ; FINN, DS; TRONSTAD, LM; MUHLFELD, CC; WEISROCK, DW; Washington State University, USGS Northern Rocky Mountain Science Center, Missouri State University, University of Wyoming, University of Kentucky; *scott.hotaling@uky.edu*
Conservation Genomics of an Alpine Stonefly Threatened by Climate Change
Climate warming is causing rapid loss of glaciers and snowpack in mountainous regions worldwide. These changes are predicted to negatively impact the habitats of many range-restricted species, particularly endemic, mountaintop species dependent on the unique thermal and hydrologic conditions found only in glacier and snowfed alpine streams. *Zapada glacier* (Order Plecoptera: Family Nemouridae) was recently petitioned for listing under the U.S. Endangered Species Act due to climate change-induced habitat loss. *Zapada glacier* is known from 10 streams and three mountainous regions, Grand Teton National Park, the Absaroka-Beartooth Wilderness, and Glacier National Park, all within the Rocky Mountains. Evidence from the mitochondrial genome indicates contemporary but rare gene flow among mountain ranges, and much lower genetic differentiation among populations versus ecologically similar, confamilial species. Here, we incorporated a nuclear genome-wide perspective via double-digest restriction-site associated DNA sequencing (ddRAD) to better characterize population structure, demographic history, and species boundaries within this imperiled species.

16-7 HOUSLAY, TM*; PRENTICE, P; WHITE, SJ; YOUNG, AJ; EARLEY, RL; WILSON, AJ; University of Exeter, University of Alabama; *t.houslay@exeter.ac.uk*
The Quantitative Genetics of Stress Coping Styles in the Trinidadian Guppy
Individuals of the same species vary in how they react to challenging situations in order to re-establish homeostasis. These ‘coping styles' comprise a suite of correlated behavioral and neuroendocrine traits, thought to vary on an axis from ‘reactive' to ‘proactive' types. Reactive individuals should be more risk-averse and flexible in their behaviors, show higher levels of stress hormones, and react strongly to environmental cues; proactive individuals should be bolder, more consistent, and show lower stress hormones and reactivity. While artificial selection experiments suggest an underlying genetic component to coping style variation, these studies have typically focused on the bimodal end product. Here, we instead estimate the quantitative genetic (co)variation in risk-related behaviors, behavioural consistency, and stress hormones in the Trinidadian guppy (*Poecilia reticulata*). We show that there is significant genetic variance in, and covariance among, risk-related behaviors. However, at neither the individual nor the genetic level did this behavioural variation conform to a simple ‘reactive - proactive' continuum as posited by the original verbal models of coping styles. We find genetic variation in not only ‘baseline' cortisol, but also in the ‘reactivity' of cortisol production to stressors. We then show genetic variation in the consistency of behavior, indicating a heritable component to how ‘predictable' animals are. By assessing genetic (co)variation in a multivariate framework, we present an overall view of the underlying genetic links among stress-related traits, and how this covariance structure can shape or constrain the response to selection in natural populations.

132-4 HOWE, SP*; ASTLEY, HC; University of Akron, Biomimicry Research and Innovation Center; *sph43@zips.uakron.edu*

Examining Turn Kinematics in Fish for the Control of Biomimetic Fish Robots

Fish are capable of a wide range of maneuvers which they seamlessly integrate with their undulatory locomotion. As such they have been models for designing autonomous under water vehicles (AUVs). To date, fish robots have been designed to maneuver using two basic modes of turning. The first is a waveform offset in which the frequency and amplitude of the oscillation remain unchanged, but the entire wave is biased to the right or the left, causing the fish to favor bending in one direction. The second is akin to the c-start maneuver in fish, in which a maximum amplitude deflection is simultaneously applied to all joints of the body to one side, interrupting the typical locomotor body oscillations. Based on preliminary video data, we suggest a new mode called a "bending pulse" wherein a peak of a given amplitude is propagated down the body from head to tail, unlike c-starts in which bending is simultaneous at all points along the body. By using high speed video to analyze the kinematics of turning in the giant danio (*Devario aequipinnatus*), we intend to quantify the turning strategies of fish, implement those strategies in a biomimetic, 3D-printed fish robot, and compare the robot's turning performance using both bioinspired and other turning strategies. Through our video analysis and use of robot models we hope to better understand how fish exert fine motor control over a wide range of maneuvers, and apply that understanding to better design and control of biomimetic AUVs.

P3-24 HOWELL, KA*; RICHARDS-ZAWACKI, CL; University of Pittsburgh; *kih21@pitt.edu*

Does larval color vision contribute to the development of adult mate preferences?

Imprinting can play an important role in the development of mate preferences. However, as imprinting is usually based on visual cues, the functionality of this mechanism depends heavily on the visual capabilities of the young animal. For imprinting to work, the young organism must have a visual system that is developed enough to enable the animal to perceive variation in the trait used in mate choice selection. In species where mate preference is color-based, this suggests that young animals must have color vision. We hypothesize that imprinting provides a mechanism for color-associated mate preferences in the tropical poison frog *Oophaga pumilio*, a species made up of a wide diversity of color morphs. Cross fostering experiments suggest that imprinting at the tadpole stage may be important for the development of female mate preferences in this species. However, we do not know anything about color vision in tadpoles. Experiments aimed at quantifying the visual system of these tadpoles and their ability to discriminate between colors are needed to determine how imprinting may influence mate preference. Here we examine tadpole ability to discriminate color using model frogs painted to mimic several color morphs. Our results will expand our understanding of the color vision capabilities of tadpoles and the role that sensory systems play in imprinting.

39-5 HOWEY, C.A.F; The University of Scranton; *christopher.howey@scranton.edu*

Restoration of Timber Rattlesnake Gestation Sites: Efficacy of Daylighting Management

The range of Timber Rattlesnakes (*Crotalus horridus*) extends further north than most other rattlesnakes. In these colder, northern latitudes, pregnant female *C. horridus* must use rare, open habitats (gestation sites) in order to elevate body temperatures necessary for successful embryonic development. Unfortunately, many of these gestation sites are becoming overgrown with vegetation and it is believed females occupying these sites will no longer be able to maintain preferred body temperatures and reproductive fitness will suffer. For the past two summers (2016 and 2017) pregnant *C. horridus* were radio-located at six rookery sites; four of which have become overgrown with vegetation. At each site, available operative temperatures, canopy cover, and presence of potential predators was measured. Body temperatures of females were recorded every hour throughout the entire summer; as were behaviors, date of parturition, and estimated litter size. Between the two summers, trees were removed surrounding three of the six rookery sites using a targeted disturbance called "Daylighting". Operative temperatures increased as canopies became more open. During the first summer, gravid females occupying more enclosed rookery sites dropped litters at a slightly later date, abandoned rookery sites, aborted their litters, and mothers suffered increased mortality. I will further discuss body temperatures maintained by females at rookery sites, and the efficacy of Daylighting management. Dependent on the success of this restoration technique, these management techniques can be applied throughout the species northern range to increase female reproductive success.

P2-159 HOYVEN CISNEROS, IN*; SHANKAR, A; POWERS, DR; George Fox University, Newberg, OR, Stony Brook University, Stony Brook, NY; *icisneros14@georgefox.edu*

Patterns of Nighttime Body-Temperature Regulation in Hummingbirds

Torpor is an adaptive mechanism that utilizes short-term hypothermia to reduce daily energy costs via a reduction in metabolic rate. Hummingbirds are well known for their ability to enter a state of deep torpor, in which body temperature (T_b) can decrease by >30°C. T_b during torpor drops passively so that the depth of torpor is limited by nighttime ambient temperature (T_a). Climate change has caused nighttime temperatures to increase more quickly than daytime temperatures, which could reduce energy savings during torpor. Our recent nighttime metabolic data for hummingbirds has suggested that some species use regulated shallow hypothermia. Regulated shallow hypothermia, where T_b drops only a few degrees, is commonly used by many birds and mammals, and allows for some rest-phase energy savings without the physiological or ecological consequences that can occur with deep torpor. Because regulated shallow hypothermia does not require costly rewarming, its use on warm nights could result in meaningful energy savings. We used infrared thermography to track overnight changes in skin surface temperature (T_s) in blue-throated (*Lampornis clemenciae*; 8.0g), Rivoli's (*Eugenes fulgens*; 7.5g), and black-chinned (*Archilocus alexandri*; 3.0g) hummingbirds in the Chiricahua Mts., SE Arizona. Deep torpor was used by 58% of all birds (n=12), with one bird (a Rivoli's) using regulated shallow hypothermia for 6 hours. During this bout of shallow hypothermia, T_s only decreased ~8 °C below normothermic T_b, and was regulated 13-15°C above T_a. The fact that one bird used regulated shallow hypothermia may suggest that hummingbirds can regulate body temperature above their minimum set point for deep torpor. Shallow hypothermia could be a useful strategy for saving energy on the warming nights resulting from climate change.

31-8 HSU, CT; BHANDAWAT, V*; Duke University;
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Principles underlying control of multi-jointed limbs
The precise control of multi-jointed limbs is central to our ability to perform a vast array of behaviors. Multi-jointed limbs allow an animal to tune its motor output finely, but controlling the many degrees of freedom resulting from multi-jointed limbs is a well-recognized challenge. A central question in motor control is how the nervous system transforms larger behavioral goals into the complex computations necessary for the moment-by-moment control of multi-jointed limbs. Here we employ genetics, in-vivo electrophysiology, and quantitative analysis of leg kinematics to determine the respective contribution of circuits in the brain, circuits in thoracic ganglia, and sensory feedback to the generation of limb movements. By manipulating central control and sensory feedback under diverse preparations, we come to four conclusions regarding the control of leg movements in Drosophila. First, without sensory feedback from the environment, inter-leg coordination is almost completely disrupted. Second, in contrast to inter-leg coordination, many aspects of intra-leg coordination remain intact. In particular, retraction-protraction (RP) and extension-flexion (EF) are flexibly coordinated by central circuits such that a vast majority of movement epochs can be classified into a small number of discrete movement-types. Third, maintaining this structured movement requires descending inputs from the brain. Fourth, feedback from the environment seems critical for eliciting levation-depression movements which in turn structures movement into alternating stance and swing phases. We use this framework to differentiate how descending neurons (DNs) from two different parts of the brain shape motor output. In sum, there is a division of labor between feedforward and feedback which represents an elegant solution to the "degrees of freedom" problem.

115-2 HU, Y.*; MCMENAMIN, S.K.; Boston College;
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Parsing the roles of thyroid hormones in developmental regulation: a survey of phenotypic features in hypothyroid zebrafish.
Thyroid hormones play numerous essential roles in vertebrate development. A century of research has demonstrated that these endocrine factors have numerous physiological and developmental functions. From cells to whole organisms, they participate in the regulation and coordination of many biological processes, and abnormal production of thyroid hormones underlies a variety of human disorders. Advances in molecular technology offer the opportunity to study the cellular and developmental functions of thyroid hormones in detail. To determine the mechanisms by which these hormones mediate development, we utilized a stable transgenic zebrafish line, *Tg(tg:nVenus-2a-nfnB)*, that allowed us to conditionally ablate the thyroid follicles. We performed the ablation early in ontogeny and let the fish develop without thyroid hormones through adulthood. Focusing on poorly-understood post-metamorphic stages, we examined changes in various traits across ontogeny. We are analyzing body and facial shape, neuromasts of the lateral line, the olfactory organ, taste buds, eye, inner ear, fins, axial skeleton, scales, and adipose tissue at multiple developmental stages. In particular, we found that ossification and remodeling of both craniofacial and axial skeletons were highly dependent on thyroid hormones. Contrary to expectations, we found that thyroid hormones inhibited proliferation of superficial neuromasts in the head, but not along the body. These analyses provide a foundation for discovering thyroid hormone-mediated developmental mechanisms.

23-6 HUANG, V*; LUBIN, F; University of Alabama at Birmingham; *victoriahuang@uab.edu*
Stress Experience on the Zebrafish Brain
A period of environmental disturbances can influence an individual's brain and behavior, even after the end of that experience. Zebrafish (*Danio rerio*) have distinct behavioral, physiological, and neuronal responses to stressors. We were interested in how chronic stress is mitigated in the zebrafish brain, further, we hypothesized that chronic stress would affect learning and memory-associated gene expression. To address this question, we chronically stressed male and female adult zebrafish with unpredictable environmental changes, and subsequently compared their locomotor behavior to unstressed zebrafish. In addition to the behavior approach, we looked at candidate stress- and memory- associated gene expression in the whole brain. After chronic stress exposure, both males and females exhibited a decrease in *hsd11b2* expression, which could be from translation to protein to deactivate cortisol. In chronically stressed vs unstressed females, there was a higher *ache* expression, which is found to impair memory in mammal and other teleost studies. However, the difference was not seen in males. Zebrafish in all groups spent most of the time at the bottom half of the novel tank, and in stressed versus unstressed males, there was less total swimming distance. While chronic stress experience altered gene expression in the whole brain, and telencephalon-specific studies will better elucidate potential altered learning and memory from this experience.

36-8 HUBEL, TY*; GOLABEK, K; RAFIQ, K; MCNUTT, W; WILSON, AM; Royal Veterinary College; *thubel@rvc.ac.uk*
Movement patterns and hunting performance in leopards
Leopards are the most widespread of all the big cats and are known for their adaptability. Despite this, leopards are elusive and little is known about their lifestyle. We use high-resolution GPS/IMU (inertial measurement unit) collars to record position, speed and activity of four male leopards in the Okavango Delta, an area with high habitat diversity as well as habitat fragmentation. Data were generally recorded at 5 minute intervals, but allowed to trigger into high resolution mode (5Hz GPS/50Hz IMU) for a total of 5 months in order to capture run occurrence and performance. Data shows that the animals are mainly active during the night with peaks in activity occurring in the early morning and evening. Runs occurred more frequently during the night with a slight increase in the early morning hours. Runs were generally short (<100 m) and relatively slow (an average speed of 6 m/s). Average daily travel distance was 11 km and maximum daily travel distance was 30 km. No direct correlation was found between average daily temperature and travel distance. However, leopards showed surprisingly similar patterns in average monthly travel distance over time, suggesting that factors such as mating opportunities, grass height or food availability have a similar influence on different individuals. Total daily energy requirements based on locomotor cost and basal metabolic rate varied little among individuals and over time.

90-6 HUDSON, SB*; SMITH, GD; DURSO, AM; FRENCH, SS; Utah State University; *spencerbrucehudson@gmail.com*

Selection Across an Urban-Rural Landscape in Side-blotched Lizards Uta stansburiana

Urbanization is a major disturbance threatening habitats worldwide, yet there is limited information on how wildlife populations are responding to rapidly changing landscapes. When habitats are altered, persisting species can demonstrate physiological shifts in life history strategies due to novel challenges. Life history theory predicts phenotypic differences among populations to emerge from different selective pressures. Physiological differences in life history traits can thus arise from intraspecific genetic differentiation and environmental effects on gene expression. Emerging studies in side-blotched lizards *Uta stansburiana* suggest such selection potential through population-level physiological responses to urbanization, but the genetic signatures of recent evolutionary change remain largely unexplored. We hypothesized that local adaptation to urbanization has contributed to life history divergence between populations of side-blotched lizards. By assessing genetic time-series data, we inferred evolutionary trajectories for ecological specialization in urban and rural lizard populations. Such analysis included single nucleotide polymorphisms (SNPs) generated by double digestive RAD sequencing. We calculated average allele frequency changes across SNPs to infer effective population size and estimate variable selection across the genome. This approach revealed the degree to which standing genetic variation among heterogeneous environments is likely to enable physiological shifts in life history traits.

P1-90 HUEBNER, CD*; CLARK, RM; WILLIAMS, CM; Univ. of California, Berkeley; *christopherhuebner@berkeley.edu*

Development of Activity Patterns in Wing-Dimorphic Crickets During Early Adulthood

When an organism transitions into a new life stage, it often must adjust its behavior to respond differently to environmental cues. Typically, in the transition from juvenile to adult, resources must be directed away from growth/development and put either toward dispersing or finding a mate and reproducing. In wing-dimorphic *Gryllus* crickets, during early adulthood individuals specialize either in reproduction or dispersal. This is likely to influence how they organize their activity, but nothing is presently known about how locomotor patterns change over the course of early adulthood. We predicted that there would be differences between the dispersal and reproductive morphs apparent during the night following day 5, because that is a critical age and time at which the dispersal morph is prepared for its dispersal flight. We examined these activity patterns across both day and night in individually reared crickets, kept in an incubator at 27° Celsius with a cycle of 16 hours light and 8 hours dark. Using Biotracker, we compared the total movement of each individual from days 0 to 1 of adulthood to its total movement from days 5 to 6. Our data show that crickets moved greater total distances from days 5 to 6 than they did from days 0 to 1. This increase occurred only at night. Surprisingly, there was no difference in total nighttime movement between morphs. Therefore, there is evidence that circadian organization of locomotion increases over the course of adulthood, but other stimuli may be necessary to trigger the increased activity associated with dispersal flight.

P2-60 HUEY, B; GIES, RA*; BATAC, F; BECK, J; COHEN, CS; Romberg Tiburon Center, San Francisco State University, CA, CA Dept. of Fish & Wildlife - Office of Spill Prevention & Response, Santa Cruz, CA, CA Dept. of Fish & Wildlife - Office of Spill Prevention & Response, Santa Cruz, CA; Oikonos Ecosystem Knowledge, Santa Cruz, CA; *rgies@mail.sfsu.edu*

Identification of Acanthocephalan Parasites from Southern Sea Otters and Sea Birds: A Comparison of Molecular and Morphological Methods

Parasitic acanthocephalan species have complex life cycles utilizing both intermediate and final hosts. These parasites have deleterious health impacts on their vertebrate hosts, including lethal peritonitis in some genera. Given the morphological similarity of these parasites, molecular analysis improves our understanding of their diversity and distribution. Dried acanthocephalan samples from necropsied Southern sea otters (Enhydra lutris nereis) and sea birds (Melanitta perspicillata, Phalacrocorax penicillatus, and Podiceps nigricollis) were obtained from the California Department of Fish and Wildlife. Mitochondrial cytochrome oxidase 1 (CO1) and nuclear 18S ribosomal RNA (18S rRNA) sequences were obtained and used to identify genera. Eighteen acanthocephalan samples from eleven otters were successfully sequenced. Corynosoma sp. were identified in fourteen samples, and Profilicollis sp. were identified in three. One otter had both Corynosoma sp. and Profilicollis sp. present. Samples from six individual birds were used to identify Pseudocorynosoma sp. (n=2), Corynosoma sp. (n=2), and Profilicollis sp. (n=2). These results demonstrate the ability of molecular sequencing to confirm or refute identification by morphological methods. A re-examination of morphological characters in light of molecular data may provide new insights into morphological traits that are most robust for future identification, or indicate species that will be best served by molecular analysis.

95-4 HUFFMYER, AS*; GATES, RD; University of Hawaii, Hawaii Institute of Marine Biology; *ashuff@hawaii.edu*

Thermal Conditioning and Heterotrophic Feeding Enhances Resilience in Juvenile Corals

Thermal stress from ocean warming destabilizes the nutritional symbiosis between corals and their intracellular dinoflagellate symbionts *Symbiodinium* spp., a response that results in an energy deficit for the coral host. Coral hosts with large energy reserves or those that compensate for the loss of energy by heterotrophic feeding may have a greater chance of surviving warming conditions. Recent research has focused on the response of adult corals to thermal stress, however, it is unclear how the post-settlement environmental or the nutritional condition of early life history stages shape their performance and survival under thermal stress. We evaluated the effects of conditioning regimes on the growth, survivorship, and thermal stress response of juvenile *Pocillopora acuta* corals. Larvae collected from parental colonies in Kāneʻohe Bay, Hawaiʻi were settled and exposed to cool (25.7°C) or ambient (27.3°C) temperature in filtered seawater (1µm) in the presence or absence of a heterotrophic food source. Juvenile colonies were exposed to these temperatures for one month and then exposed to a thermal stress test (max. temperature ca. 32°C). After one month, there was a positive effect of cool temperature on survivorship, and a positive effect of heterotrophic feeding on growth. During the thermal stress test, there was an interactive effect of temperature and heterotrophic feeding on juvenile performance, indicating that these conditions play complex roles in shaping physiological responses. These results suggest that cool seasonal periods and heterotrophic feeding enhance the resilience of corals to thermal stress events.

96-7 HUGHES, DF*; GIGNAC, PM; GREENBAUM, E; KHAN, AM; University of Texas at El Paso, Oklahoma State University; *dfhughes@miners.utep.edu*

Field-Based Brain Tissue Preservation Methods and Comparative Multi-Scale Structural Analyses Reveal the Cranial Diversity of Chameleons

How do traits vary across the tree of life? Our ability to address this question is diminished when species go extinct. In the era of mass extinctions, it is imperative to accelerate data-rescue efforts before poorly understood species are lost. However, traditional specimen preservation does not permit researchers to consistently retrieve neuroanatomical data at high resolution. We experimentally developed a protocol using novel field-based procedures for brain preservation while collecting chameleons in Africa. We found that brain tissues preserved under remote field conditions were comparable to laboratory prepared tissues. Further, immunostaining for small neurotransmitter and neuropeptide biomarkers were similar between our comparisons. Concordantly, our field-preservation approach was tractable with diffusible iodine-based contrast-enhanced computed tomography (diceCT), allowing for the documentation of soft-tissue structures. We integrated our field-based protocol into a pipeline that aims to examine the cranial diversity of chameleons. This pipeline involves CT-scanning field-collected specimens to reconstruct high-density tissues. The same specimens are next stained with Lugol's iodine (I2KI) and re-scanned to visualize soft-tissue structures. Finally, tissues are then de-stained and used for histological preparations to examine cytoarchitectural features. Our results set up the potential for comprehensive, comparative approaches to elucidating the cranial diversity of poorly known and often inaccessible species across micro- to macroscopic scales of analysis.

P2-192 HUH, KM*; WRIGHT, N. A.; TOBALSKE, B. W.; Tulane University, Kenyon College, University of Montana; *khuh@tulane.edu*

Sexual Difference in the Escape Flight of the Calliope Hummingbird (Selasphorus calliope)

Sexual dimorphism is widespread in bird species, but the consequences of this dimorphism upon flight performance is not well understood. Hummingbirds are useful models for studying the biomechanics and physiology of avian flight. Most studies of hummingbird flight are conducted in controlled conditions in the lab, and only recently have techniques made it feasible to examine details of their flight outdoors. In hummingbirds, males typically have smaller body mass, lower wing and disc loading, and larger flight muscles than females. We undertook the present study to test whether sexes differ in escape performance during free-flight in the field. We used high-speed video (three Hero3 Black GoPro, synchronized) to record 15 flights of male and 17 flights of female *Selasphorus calliope* escaping from a startle perturbation while they were foraging at an outdoor feeder. Peak and average velocities were almost the same in both sexes. Peak and average accelerations were higher in male hummingbirds, but only the latter difference was statistically significant (peak acceleration, $p = 0.38$, average acceleration, $p < 0.05$). Overall, male hummingbirds were found to perform shorter, more accelerated flight than females in the field during escape. This result suggests sex should be taken into account when testing hypotheses of hummingbird flight performance and behavioral ecology.

P1-24 HUIE, JM*; EVANS, KM; SUMMERS, AP; KOLMANN, MA; Unv. of Washington, Univ. of Minnesota, Univ. of Washington, Univ. of Washington; *jmhuie@uw.edu*

Ontogeny of jaw biomechanics in lepidophagous fishes

Although rare within the context of 30,000 species of extant ray-finned fishes, scale-feeding has evolved repeatedly across this branch of the tree of life. Scale-feeding (lepidophagous) fishes are diverse in terms of their ecology, morphology, and behavior, using strategies such as mimicry and ambush tactics, coupled with specialized cranial morphologies to graze off the scales and mucus of sympatric species. We examined the ontogeny of feeding mechanics in two scale-feeding characiform fish lineages: *Roeboides*, a characin, and *Catoprion*, a piranha. We compared these two scale-feeding specialist taxa to their nearest, non-lepidophagous taxa to identify traits held in common among scale-feeding fishes. We use a combination of micro-computed tomography scanning and iodine staining to measure biomechanical predictors of feeding behavior such as tooth shape, jaw lever mechanics, and jaw musculature. We recover a stark contrast between the feeding morphology of scale-feeding and non-scale-feeding taxa. Lepidophagous fishes display paedomorphic characters through to adulthood, such as a stout teeth and a small jaw muscles. However, few traits are shared between lepidophagous characins and piranhas, except for their paedomorphic, highly-modified, stout dentition. We suggest these robust teeth are critical to resisting the impact incurred when these scale-feeders pry or dislodge scales from prey during ram-feeding. Lepidophagous taxa are prime examples of equifinality in explaining the diversity of form and function across teleost fishes: there are many ways to adapt to the scale-feeding niche.

P2-61 HULBERT, AC*; GARCIA, J; REFSIDER, JM; Auburn University; Lake Erie Center, University of Toledo, Lake Erie Center, University of Toledo; *austinhulbert@aol.com*

The Relationship Among Parasites, Algal Growth, and Immune Activity in Freshwater Turtles

Vertebrate animals host a diverse community of internal and external parasites, the composition of which may interact with an individual's immune functioning. Parasites of reptiles are particularly under-studied, and the interplay between parasites and immune functioning in reptiles is only beginning to be understood. We investigated the variation of parasitism by leeches and hemoparasites in two freshwater turtles, the midland painted turtle (*Chrysemys picta marginata*) and the northern map turtle (*Graptemys geographica*), in Ottawa County, Ohio in May-June 2017. We also assessed the relationship between leeches and shell algae. Finally, we investigated the relationships of parasitism and shell algae with the immune activity of turtles as measured by the skin-swelling response to a phytohemagglutinin challenge. The percentage of turtles infected with parasites (prevalence) and mean leech intensity (number of leeches) were similar for both turtle species, possibly because both species bask often and leeches may selectively choose hosts based on basking behavior. We detected a positive relationship between leech intensity and shell algae in painted turtles, but not map turtles. Infection status (i.e., parasitized by leeches only, hemoparasites only, both [co-infected], or neither), leech intensity and shell algae did not correlate with immune activity for either species. As a result of coevolution, the relationship between these parasites and their turtle hosts might currently be in a state of commensalism on the spectrum of symbiotic relationships. However, other measures besides immune activity, such as immunocompetence, are needed to fully assess the interactions between parasites and the complex immune system of turtles.

50-6 HULETT, R.E.*; SRIVASTAVA, M.; Harvard University;
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Where is my mind: Nervous system regionalization in the acoel Hofstenia miamia

Bilaterians with clear anterior-posterior (AP) and dorsal-ventral (DV) axes represent a major transition in early animal evolution. Most bilaterian lineages show a restriction of the central nervous system (CNS) along the DV axis, ventrally in protostomes and dorsally in chordates. The DV axis and the accompanying CNS regionalization are generally controlled by Bmp (Bone morphogenetic protein) signaling across many bilaterians. Acoels, members of the outgroup lineage to all other bilaterians, have a DV axis under Bmp control, but their nervous system is not restricted to one side. Previous studies have supported the idea that the role for Bmp/Chordin in axial patterning may have preceded a role in neural patterning. Therefore, studies of the nervous system patterning in acoels can reveal the evolution of the mechanisms through which Bmp signaling controls the nervous system. We utilized *Hofstenia miamia*, an acoel species that is amenable to functional investigation of nervous system patterning during both development and regeneration. As a first step, we sought to determine the nervous system architecture of *H. miamia* by identifying and characterizing its neural genes. We identified homologs of all major neurotransmitter synthesis pathway genes as well as neurotransmitter receptors in the *H. miamia* transcriptome. Based on fluorescent in situ hybridization, we found three major subepidermal regions along the anterior-posterior axis that contain a diversity of neural cell types - an oral "ring", an anterior domain with ventral lobe-like structures, and the remainder of the body with sparsely-distributed cells. The identification of these major neural subpopulations will enable a functional investigation of mechanisms that control the localization of neural cells along the DV axis.

7-5 HULSE, SV*; MENDELSON, TC; UMBC;
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The Efficient Coding Hypothesis and Signal Design

The efficient coding hypothesis posits that organisms' sensory systems evolve to represent environmental stimuli in a way that is the least metabolically or developmentally costly. One way this can be accomplished is by removing statistical redundancies from sensory inputs to minimize the number of spiking neurons required to represent a stimulus. In the context of visual perception, the mammalian visual cortex is thought to perform these computations. Since visual statistics vary by habitat type, the efficient coding hypothesis would predict that species will evolve to most efficiently encode their species-specific visual habitat. This is a potential route for the diversification of sexually selected signals. Many studies in humans and non-humans have shown preferences for efficiently coded stimuli. If males can mimic the visual statistics of their environment, it could increase their perceived attractiveness to females. Using darters (genus Etheostoma) as a model system, we show quantitative differences in the visual statistics of individual species' habitats as well as preliminary data on how environment relates to the sparseness of visual displays.

44-6 HULSEY, CD*; MEYER, A; Univ. of Konstanz, Germany;
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The Genomic Architecture of a Key Innovation and Evolution of Dental Divergence in East African Cichlid Fishes

Using a hybrid mapping cross of two Lake Victoria cichlid fish species, we examined genomic regions associated with their dental diversity. A similar genomic region was found to be associated with the most variation in oral jaw tooth numbers in cichlids from both Lake Malawi and Lake Victoria. This same genomic region was also associated with variation in pharyngeal jaw tooth number. Highly similar correlations in tooth numbers on the two jaws in both our Victoria hybrid population and across the phylogenetic diversity of Malawi cichlids suggests teeth in haplochromine cichlids might generally coevolve according to their shared genetic basis.

19-7 HUNT, KE*; BUCK, CL; WILLING, C; DILLON, D; JøRGENSEN, MPH; FERGUSON, S; MATTHEWS, CJD; N Arizona Univ, Fisheries and Oceans Canada, Greenland Institute of Natural Resources, Fisheries and Oceans Canada;
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Evidence of annual testosterone cycles in baleen of a male bowhead whale (Balaena mysticetus)

Mysticete whales are generally assumed to have seasonal reproductive cycles, inferred from seasonal timing of births. However, due to difficulties in obtaining endocrine samples from large whales, there is little direct evidence for potential annual cycles in the reproductive hormones. We have recently demonstrated that steroid hormones accumulate in whale baleen as it grows, such that a single piece of baleen contains a multi-year timeline of hormones along the length of the baleen plate. In females, reproductive events such as pregnancy can be accurately reconstructed from hormone profiles in baleen, but males have not yet been investigated. We present here the first testosterone data from baleen of a male whale, using a baleen plate of a single adult male bowhead (*Balaena mysticetus*) as an initial test case. Baleen was sampled every 2 cm along the 204 cm plate. Steroid hormones were extracted with a methanol vortex method, and testosterone was assayed with an EIA previously validated for bowhead baleen. Testosterone was detectable in all samples and showed prominent repeating cycles, with thirteen peaks evenly spaced every 16-17 cm along the full length of the baleen plate, corresponding well to estimated annual baleen growth rate for male bowheads of this size class. Though data are as yet limited to a single case study, the regularly spaced peaks match predictions for annual testosterone cycles, and suggest that whale baleen may prove a fruitful resource for investigation of reproductive cycles in the mysticete whales.

71-7 HUNT VON HERBING, I.*; SCHROEDER-SPAIN, K.; University of North Texas, Texas A & M University Corpus Christi; *vonherbing@unt.edu*

Hb Polymerization in Red Blood Cells of Marine Fishes: A case of phenotypic plasticity and environmental sensing?

Hemoglobins (Hbs), widespread in all living organisms, descended from an ancient ancestral gene and serve many functions, including transporting of oxygen. In the present study, frequency of occurrence and function of the unusual phenomenon of Hb polymerization, which can cause distortion or sickling of red blood cells (RBCs) similar to human sickle cell disease, was investigated in 47 species of fishes. In a 9 year survey of three ecosystems, east and west sides of the Atlantic Ocean, and Gulf of Mexico, 32% of species sampled (15 species in 5 orders, 9 families) exhibited Hb polymerization in RBCs under low O2 and pH conditions. Transmission Electron Microscopy (TEM) verified presence or absence of Hb polymers at the cellular level, in vitro for 12 species, and in vivo for Atlantic cod (Gadus morhua), revealing that while intensity and morphology of Hb polymers varied across species, they were not independent of phylogeny and present in all Gadiformes. Moreover, purification and recrystallization of Atlantic cod Hb validated previous results (Harosi et al., 1998) that Hb polymerized independent of other cellular components. Finally, effects of pH (6.99 - 7.99) on Hb polymerization intensity in two related boreal species, Atlantic cod (G. morhua) and Oyster toadfish (Opsanus tau) found strong, reversible pH dependence with ~ 50% of all RBCs containing Hb polymers at ~ pH 7.6 in both species. We propose; Hb polymerization in RBCs is wider spread than previously thought, and likely evolved independently across diverse fish taxa. Hb's that polymerize may exhibit unusual physiological and structural plasticity, conferring innate immunity, as well as acting as an environmental sensor, sensitive to changing oceanic conditions.

92-2 HURD, PL; Univ. of Alberta; *phurd@ualberta.ca*

Sexual selection, and isotocin neural phenotype differences in a cichlid with alternative male morphs

Males of the Kribensis cichlid *Pelvicachromis pulcher* exist in one of four different morphs, commonly distinguished by differences in the colour of their opercula and belly. The two most common morphs, "red" and "yellow" will both breed monogamously, but red males show preference to haremic breeding, while yellows do not. It has been suggested that yellows may follow a "satellite" strategy, or serve as subordinate helpers to harem holding males. The two morphs show behavioural differences. Red males grow more slowly, but are more active than yellow males; they also tend to use more escalated aggressive behaviours than yellow males. Here we present analyses of male-male contest behaviour between the morphs, and experiments measuring female preference for colour morph and other potentially sexually selected characters. We also examine differences in nonapeptide expression in the preoptic area of the hypothalamus which show differences between morphs, as well as variation within morphs associated with individual variation in social behaviour.

P2-95 HUTCHINSON, JR*; SUMNER-ROONEY, L; REGNAULT, S; Royal Veterinary College; Structure & Motion Lab, Oxford University Museum of Natural History; *jrhutch@rvc.ac.uk*

Convergent Evolutionary Origins of the "Predigits" of Mammals

It is now well known that numerous mammalian taxa including moles, pandas and elephants have sizeable mineralized structures on the medial side of the manus and/or pes referred to as the prepollex or prehallux ("predigits" collectively), among other names. It is often assumed that these are enlarged sesamoid bones, and it has indeed been demonstrated in several cases that described "predigits" are homologous to radial or tibial sesamoids in their presumed plesiomorphic non-enlarged state. We compiled published data and original observations to reconstruct the evolutionary history of radial/tibial sesamoids, specifically whether "predigits" always evolved from these precursors, and how many times they did. We applied maximum parsimony and likelihood character evolution reconstruction methods to these data on a time-calibrated evolutionary tree of Mammaliaformes. We found that there are many more unrecognized origins of "predigits" in other lineages, and that both radial and tibial sesamoid bones have evolved convergently multiple times within crown group Mammalia. These results prompted us to speculate that the bony sesamoids themselves evolved from an ancestral precursor made of soft tissue such as ligament, tendon, cartilage, and/or fibrocartilage, or a series of those states. More studies of the ontogeny and anatomy as well as the distribution of these features in mammals and their fossil outgroups are needed to refine and test these inferences of homology and evolution.

49-8 HUTCHINSON, BL*; SOUTHWARD, SC; BAYANDOR, J; Virginia Tech, State University of New York at Buffalo; *blgater@vt.edu*

Amplitude Effects on Thrust Production for Undulatory Swimmers

Biological systems offer novel and efficient solutions to many engineering applications, including marine propulsion. It is of interest to determine how fish interact with the water around them, and how best to utilize the potential their methods offer. A stingray-like fin was chosen for analysis due to the maneuverability and versatility of stingrays. The stingray fin was modeled in 2D as a sinusoidal wave with an amplitude increasing from zero at the leading edge to a maximum at the trailing edge. Using this model, a parametric study was performed to examine the effects of the fin on surrounding water in CFD simulations. The results were analyzed both qualitatively, in terms of the pressure contours on the fin and vorticity in the trailing wake, and quantitatively, in terms of the resultant forces on the fin. The amplitude was found to have no effect on the average thrust during steady swimming, when the wave speed on the fin was approximately equal to the swimming speed. However, amplitude was shown to have a significant effect on thrust production when the fin was accelerating. This finding suggests that for undulatory swimmers, amplitude is less useful for controlling swimming speed, but can be used to great effect for augmenting thrust during acceleration. Ultimately, this conclusion helps explain why many fish tend increase their fin-beat amplitude more during acceleration than during cruising, even at high cruising speeds.

S10-8 HUTTON, P*; MCGRAW, KJ; Arizona State University; *pierce.hutton@asu.edu*

People, please power down the party: relative effects of human presence at night on metabolism, disease, and condition in rural v. urban finches

More than half of the Earth's human population lives within cities, which leads urban animals to come into frequent, direct contact with humans. Most considerations of human impacts on wildlife have focused on daytime hours, but after-dark human activity in cities may also serve as overlooked selection pressures (e.g. on metabolic rate, oxidative balance, disease resistance, body condition) to which urban organisms must acclimate or adapt. Thus, we hypothesized that urban animals might better cope with nighttime exposure to humans. In this experimental laboratory study, we exposed wild-caught urban and rural juvenile house finches (*Haemorhous mexicanus*) to repeated and randomized night-time intrusions by a human (i.e. who entered the darkened housing room and gently walked, while briefly rustling, the bird cages for 5 minutes). We predicted that urban birds would be resilient to the negative impacts on various physiological metrics, such as basal metabolic rate, plasma carotenoid levels (a dietary antioxidant), intestinal coccidian parasite (*Isospora* spp.) loads, and body condition. Our night disturbance treatment increased intestinal parasite loads relative to controls, but did not affect body condition. Additionally, the magnitude or presence of an effect did not appear to depend on whether the birds were caught from an urban or rural site. Despite nighttime disturbance having a possible disease-promoting effect on birds, from our results it does not appear that urban house finches have adapted to cope with this effect.

P2-89 HUYGHE, K*; VAN EECKHOVEN, J; VAN DAMME, R; Univ. of Antwerp, Univ. of Leeds; *katleen.huyghe@uantwerpen.be*

Male phenotypes produced by artificial intra- or intersexual selection in guppies

With this artificial selection experiment, we want to quantify the effects of two sexual selection mechanisms on the male phenotype in guppies. Secondary sexual traits in males are the result of a range of selection mechanisms acting on them, pushing traits in one or another direction. The outcome depends on the relative contribution of i.a. the two main sexual selection mechanisms: intra- and intersexual selection, namely male-male competition and female mate choice. In guppies (*Poecilia reticulata*), epigamic selection is believed to be the dominant evolutionary force in the elaboration of male ornaments, but agonistic interactions between males have been underestimated. In this study, we have set up breeding lines to test the individual effects of intra- and intersexual selection on male phenotypes, without possible mutual interference. A random breeding line was also maintained. We test effects after 5 generations on male appearance and behaviour, and test whether both evolutionary forces shape traits in the same way, and whether female preferences evolve accordingly within treatments.

P2-48 IBARRA, M; ROBERTS, B; LOYA, A; OKWUNWANNE, Z; SOTO, PL; HARRIS, BN*; Texas Tech University, Lubbock, Texas Tech University, Louisiana State University, Baton Rouge; *breanna.n.harris@ttu.edu*

Relationship among corticosterone, object recognition performance, and brain neuropathology in an APPswe/PS1dE9 mouse model of Alzheimer's disease

Alzheimer's disease (AD) is characterized by impaired cognitive and memory function, and behavioral changes. Associated neuropathology is marked by brain amyloid beta deposits and tau tangles. The underlying cause of AD is not fully understood, but, in-line with the glucocorticoid (GC) hypothesis of brain aging, elevated levels of stress and GC hormones are associated with severity and progression of the disease in humans and some mouse models. GCs can increase the production and toxicity of brain amyloid beta deposits and these deposits can promote GC release, suggesting a possible positive feedback between amyloid beta and GCs. However, this relationship has not been addressed in the commonly used APPswe/PS1dE9 mouse model of AD. APPswe/PS1dE9 mice produce human amyloid beta which accumulates in the brain and relates to memory and cognitive deficits. Here, we will determine if, compared to their non-transgenic littermates, 18-month-old transgenic (tg) mice: 1) have elevated baseline and post-stress GCs, 2) exhibit deficits in a short (1-hr) and longer (24-hr) term memory in the object recognition task, and 3) if GCs and memory performance are related to brain amyloid beta concentrations. We predicted that tg mice would have higher GCs and poorer memory performance, and that GCs would be positively correlated with brain amyloid beta levels. However, initial preliminary results suggest that baseline and post-stress GCs do not differ between genotypes nor do genotypes differ in object recognition performance. Additional data collection and analysis is underway. Our study will be the first to determine if GCs are related to memory and neuropathology in the APPswe/PS1dE9 mouse model of AD.

49-2 INGERSOLL, R*; LENTINK, D; Stanford Unversity, Stanford University; *riversi@stanford.edu*

How neotropical hummingbird versus bat species generate lift to hover

Both hummingbirds and nectar bats evolved the ability to hover in front of flowers providing them access to energy rich nectar. Hummingbirds have been found to generate more than a quarter of their weight support during the upstroke by inverting their wings—much more than generalist birds during slow hovering flight. In contrast to hummingbirds, bats have membrane wings which they partially fold during the upstroke. It has been hypothesized that bats generate some vertical lift force during the upstroke although the complex wake structures make it hard to quantify upstroke function through flow measurement. To compare the kinematics and aerodynamic forces generated by both groups, we caught and trained over 100 individuals spanning 18 hummingbird and 3 bat species in Coto Brus, Costa Rica. We used 3D calibrated high-speed cameras to measure wingbeat kinematics and a novel aerodynamic force platform to measure the instantaneous vertical lift force *in vivo*. This data gives us new insight into how ecology shapes the evolution of hovering flight across taxa in the same ecosystem.

139-2 INGLE, DN*; PORTER, ME; Florida Atlantic University; *dingle2014@fau.edu*
Mechanical behavior of vertebral trabecular bone varies ontogenetically in the Florida manatee
Trabeculae form the porous architecture found in long bones, and they dynamically change in vivo to support mechanical demands on the body throughout life. Bone mechanical properties of terrestrial mammals reflect the degree of species-specific precociality, and skeletons must be stronger and stiffer in those animals that are mobile soon after birth. Previous studies have shown that secondarily adapted aquatic mammals have vertebral trabecular microarchitecture that differs from their terrestrial counterparts, but we have limited understanding of aquatic bone responses to loading. We are interested in the mechanical behavior of vertebral trabecular bone and the adaptations to for a non-terrestrial environment. We investigate the mechanical properties of trabecular bone in a precocial obligate swimmer, the Florida manatee, *Trichechus manatus latirostris*, at various regions along the vertebral column and ontogenetic stages. Vertebrae were dissected and machined into rostrocaudal-oriented sections and sampled in compression. We calculated stiffness, ultimate strength, and toughness from stress-strain curves. We found that material properties increased with age; stiffness quadrupled between the perinatal and adult stage while strength doubled. On average, stiffness was significantly greater in the anterior vertebral column, but strength was similar along the column length. Material properties were twice as strong and stiff in manatee calves compared with bovine calves, and stronger compared with adult bovine bone. These data suggest that vertebral trabecular bone must be stronger in a fully aquatic mammal to power undulatory locomotion, and we can begin to better understand how the vertebrate skeleton adapted to support body mechanics in the land to water transition.

102-8 INJAIAN, A.S.*; TAFF, C.C.; PATRICELLI, G.L.; Univ. of California, Davis, Cornell Lab of Ornithology; *asinjaian@ucdavis.edu*
Experimental Anthropogenic Noise Impacts Parental Behavior, and Nestling Growth and Oxidative Stress in a Non-urban Bird
Human-produced noise—from transportation, urbanization and industry—is widespread, affecting both urban and non-urban wildlife species. Non-urban species may suffer greater consequences than their urban counterparts, as they are often more sensitive to human-induced environmental change. Studies of noise pollution show a wide range of effects on non-urban birds, such as alterations in communication, parental behavior, physiology, and reproductive success. Further experimental field studies that simultaneously investigate noise impacts on avian behavior, physiology, and reproductive success are needed. Here, we use an experimental field study to investigate impacts of short-term traffic noise exposure on parental behavior (i.e. vigilance and foraging rate), nestling growth and oxidative stress (as measured by oxidative status), and nestling fledging success in tree swallows (*Tachycineta bicolor*). Our results show negative impacts of traffic noise, despite a relatively modest playback regime (6 hours, every other day). Adults in noise-exposed territories displayed decreased vigilance earlier in the nestling period, and increased feeding rate later in the nestling period, compared to controls. However, increased feeding rate in noise-exposed nests did not compensate for noise impacts on nestlings: noise-exposed nestlings had reduced body size and increased oxidative status, compared to control nestlings. Noise-exposed nestlings had increased latency to fledge, but we found no impact of noise on fledging success. These results highlight the potential long-term consequences of short-term noise exposure (decreased nestling size and increased oxidative status) and add to a growing body of literature, showing that noise pollution can negatively impact birds through both direct and indirect pathways.

6-1 IRIARTE-DIAZ, J*; ZENO, H; BUSHNEVA, Y; Univ. Illinois at Chicago; *josdiiri@gmail.com*
The Effect of Variation of Jaw Muscles and Cranial Morphology on the Evolution of Bite Performance of Primates
Substantial variation in the structural relationships within the masticatory system (i.e., among teeth, joints, and muscles) through the evolutionary history of mammals has greatly influenced the mechanical performance of the system. These changes are typically viewed as evolutionary responses associated to specific pressures; such as the need to generate occlusal force, to resist masticatory stresses, or for delicate motor control. Thus, variation in the musculo-skeletal configuration are expected to reflect adaptations to these competing and varying demands. To evaluate the relative importance of these elements in shaping the evolution of the masticatory system necessitates adequate understanding of how variation in each factor affects the mechanical performance of the system as a whole. Using 3D models of the cranium and mandibles from 69 species of primates, we evaluated how variation in jaw muscles size and position affect bite performance within an ecological and phylogenetic framework. In addition, we modelled the effect of gape angle and condylar translation on muscle strain and muscle moment arms, as well as the effect of the elevation of the jaw joint with respect to the occlusal plane. Our data shows that relative importance of the temporalis and medial pterygoid muscles to produce bite force is affected by phylogeny but the masseter is not. Dietary differences affect the relative importance of the medial pterygoid muscle, suggesting that maybe this muscle is important for motor control to process foods of different mechanical properties. The effect of gape angle on muscle mechanics is complex, depending on the portion of the masticatory muscle (e.g., anterior vs posterior fibers).

25-6 IRSCHICK, DJ; University of Massachusetts at Amherst; *irschick@bio.umass.edu*
Creating lifelike 3D digital specimens for collections-based research
One of the most important goals of collections-based research is accurate and life-like representation of specimens that can be widely shared and used by scientists for a host of questions. The Digital Life team (www.digitallife3d.org) based at the University of Massachusetts at Amherst has focused on creating devices and devising techniques for creating lifelife 3D models of living organisms, or of organisms that appear as in life(e.g., egg shells), yet are dead. Our goal was to create camera gear that used the principle of photogrammetry, the process of converting 2D digital images to 3D models. Through work with a large group of engineers, animators, photographers and other researchers, we were able to create specialized gear (Beastcam technology) that allowed us to create high-resolution 3D models of a range of species, including live frogs and lizards, as well as other organisms. These 3D models offer significant value for a range of inquiries, including the ability to create 3D digital "voucher" specimens for collections-based research. These specimens also allow researchers to investigate a whole new line of research that was not possible with typical depictions of museum specimens.

106-2 IRVINE, SQ*; JACOBSON, RE; SILER, EM; Univ. of Rhode Island; *sirvine@uri.edu*

Connecting Water Temperature to Cell Signaling and Reproductive Physiology in Ciona intestinalis

Climate change will cause increasing seawater temperatures, which will affect the reproductive physiology of marine organisms. The reproductive phenology of many marine invertebrates is determined by temperature. In *C. intestinalis* the upper thermal limit for normal reproduction is exceeded in the summer for populations local to Rhode Island. Offspring of animals reared at elevated temperature exhibit impairment of normal development, especially when subjected to hyposaline conditions, as compared with those of parents reared at lower temperatures. We previously showed extensive changes in ovarian protein expression at a late summer temperature of 22°C compared with 18°C. In particular, certain intracellular signaling molecules were highly upregulated at the higher temperature, suggesting that they mediate the response to temperature stress. We describe CRISPR/Cas9 experiments to test this hypothesis with respect to the phosphatase adaptor protein Shp2, which is the most highly upregulated signal transduction factor in our study.

76-4 ISAACS, MR*; LEE, DV; University of Nevada, Las Vegas; *michael.isaacs@unlv.edu*

A toolkit that reveals costly mechanisms in human walking gaits.

This talk expands upon the geometrical relationship of force (**F**) and velocity (**V**) and its impact on the mechanical power profile of human walking gaits. Utilizing planar ground reaction forces generated from single footfalls; we perform a collision-based analysis that provides the weighted-averages of three descriptive geometries throughout the stride cycle: • Force angle, the direction of **F** with respect to gravity • Velocity angle, the trajectory of **V** with respect to the substrate • Collision angle, the deviation from a perpendicular arrangement of instantaneous **F** and **V** These averages coarsely describe the analyzed gait and can be used to assess the relative mechanical cost of transport (CoT_{MECH}) between strides and across individuals and populations. In order to clarify that the **F** and **V** geometries are indeed responsible for increases in mechanical cost of transport, we parsed the time-varying mechanical power contributions of single- and double-stance phases of the stride. In healthy controls, this analysis revealed that step-to-step (STS) transition mechanical work contribution decreases by 20% across the range of walking speeds. The economy of the mechanical workload throughout the distinct phases of the walking is an important concept in limiting the energetic cost of dynamic motion. The analysis described in this talk allows for a tightened focus on costly walking mechanics that contribute to the CoT_{MECH} assessment for a myriad of walking gait solutions: healthy, pathological, device-assisted, robotic, etc. In addition, this analysis reveals asymmetries between single-stance phases and the STS transitions that flank the center step and would be subject to further exploration or intervention when applied clinically.

66-7 ISHIMATSU, A; MAI, VH; MARTIN, KLM*; Nagasaki University, Japan, Pepperdine University; *karen.martin@pepperdine.edu*

Patterns of Fish Reproduction at the Interface Between Water and Air

Although fishes by nature are aquatic, many species reproduce in such a way that their embryos are exposed to air either occasionally or constantly during incubation. This study examines the ecological context and specific examples of reproduction by fishes at the air-water interface, including fishes that breathe air and those that do not. At least six types of oviposition at the air-water interface are described, with examples across taxa of teleost and some primitive species from fresh water, estuaries and sea water, with pelagic or demersal eggs. Parental care and consequences for the spawning adults and embryos are considered. The widespread, variable nature of this phenomenon across a broad taxonomic spectrum indicates repeated independent evolutionary events and strong selection pressure for fishes to protect their propagules from hypoxic waters, aquatic predation, or other pressures.

P1-183 ISSA, H*; FEIPEL, C; TATUM PARKER, T; Saint Xavier Univesity; *issa.h01@mymail.sxu.edu*

The Effects of Salt Concentrations on Solidago juncea

Nationally the use of de-icing salts has increased by over 100% over the last twenty years, and continues to rise with urban-sprawl. Road salts have been shown to have detrimental effects on native ecosystems, through soil disturbances, allowing non-native species to out compete native species. This study examined the effects of various road salts on *Solidago juncea*, while also determining its potential as a salt tolerant buffer species along nature preserves. We analyzed the effects of concentrations ranging from 250ppm-2000ppm of four common road salts on *S. juncea*, by collecting data on germination & growth rates. Also, we quantified *S. juncea's* potential for extraction of highly concentrated ions from the soil. Our data showed that when exposed to a concentration >250ppm of NaCl or MgCl2, *S. juncea* germination is <50%. When exposed to any concentration of 250ppm or > of CaCl2, germination of <17%. While a commercial road salt, with a sucrose solution that substitutes 25% percent of its mass, only inhibited germination below 50% at concentrations >2000ppm.This study is ongoing with analysis of growth data, along with ion chromatographic analysis of the mature plant. This study directly shows the dramatic effects of the road salts we choose on our natural environment.

P2-120 IVANINA, AV*; SOKOLOVA, IM; UNCC, Charlotte, NC, USA, Department of Marine Biology, University of Rostock, Rostock, Germany; *aivanina@uncc.edu*

Species-specific differences of immune- and biomineralization-related transcriptome in two oysters' congeners

Hemocytes (HCs) of marine bivalves are responsible for internal defense and shell repair. Oysters shell plays a role as a physical barrier, while immune system plays a role in protection of oysters from infections. Two congeners of oysters, *Crassostrea gigas* and *Crassostrea virginica* differ in their disease resistance and shell properties. *C.gigas* can resist a wide variety of diseases, but have a weak extracellular skeleton compared with the more disease-susceptible *C. virginica*. The physiological basis of the differential susceptibility to infections as well as shell hardness in these two closely related species remains unknown. We investigated transcriptomic profiles of immune-related and biomineralization genes in HCs, as well as the biomineralization genes in the mantle tissues of two oysters' species. Pattern recognition genes (TLR2, TLR3, TLR4, mannose receptor and killer cell lectin receptor) as well as humoral and inflammation-related genes (Big defensin, complement system protein Cq3 and Tumor Necrosis Factor) were significantly higher expressed in HCs of *C.gigas* compared with *C.virginica*. Ion transport related genes (plasma membrane Ca2+ ATPase, NHX9 and NHE3) and genes encoding extracellular matrix proteins (silk-like protein, fibronectin 3-3 and fibronectin Ankyrin, casein kinases I and II) were highly expressed in *C.virginica* tissues except for chitin synthase III, fibronectin 3-2 and nacrein which were highly expressed in HCs of *C.gigas* compared to those of *C.virginica*. Our results indicate that functional specialization of HCs on the immune defense vs. biomineralization may contribute to differences in the disease resistance of the two oysters' congeners. Supported by NSF IOS award 1557870.

1-1 IVANOV, BM*; BEAUDOIN, GMJ; WEBBER, MA; JONHSON, MA; Trinity University ; *bandre@trinity.edu*

Evolution of Androgen Receptor Distribution in Anolis Lizard Muscles

Androgens facilitate the expression of male reproductive traits in many animal species, and muscles are among the primary androgenic targets. In particular, androgens bind to androgen receptors (AR) to induce physiological changes in muscle size, strength, and energetic capacity - changes that can directly influence the behaviors in which those muscles are used. In this study, we examined AR localization in 27 species of *Anolis* lizards to test the hypothesis that the evolution of AR expression in a muscle is associated with the behavioral use of that muscle. We conducted field behavioral observations of each species to assess the frequency of copulation and dewlap (throat fan) display, and used immunocytochemistry to quantify AR distribution in the nuclei of the retractor penis magnus (RPM; a muscle that moves the hemipenes in copulation) and the ceratohyoid (CH; the muscle that moves the dewlap). Our preliminary analyses suggest that larger species express less AR in the RPM. Further, while species' copulation rate is not associated with AR localization in the RPM, circulating testosterone levels were positively correlated with copulation. This suggests that AR in the RPM may play less of a role in mediating copulation behavior than its primary ligand. However, previous work has shown that dewlap display rates are not associated with circulating testosterone. Our current work examines the evolution of AR in the CH to determine whether AR localization is correlated with use of the muscle, which occurs up to several times per minute. Together, these analyses represent the largest comparative study of hormone receptors to date.

68-6 IYENGAR, EV*; MAYOL, M; Muhlenberg College; *iyengar@muhlenberg.edu*

Comparative ecology of the native banana slug (Ariolimax columbianus) and a comparably-sized invasive species of terrestrial slug (Arion rufus) in Washington state

As nocturnal detritivores, slugs have a large, but often unrecognized, role in nutrient cycling within many ecosystems. The banana slug (*Ariolimax columbianus*) is the second-largest terrestrial slug in the world and had no comparably-sized competitors in its evolutionary history until *Arion rufus* was introduced from Europe within the last century. Transect surveys over the past four summers on San Juan Island, Washington state, indicate that the relative frequency of these two slug species is shifting dramatically in some locations, with the invasive species becoming much more common than the native banana slug, perhaps in part due to impacts of drought. These two species (even the invasive species from different microhabitats) have similar food preferences and general feeding rates. While the slugs' catholic diet on relatively common foods may reduce competition, they both demonstrated a very strong preference for particular moist food items that are ephemeral and patchily distributed. This preference may indicate that particularly limited resources, especially for moisture in dry seasons, produce intense competition, and that the invasive species is a superior competitor to the native species in accessing these ephemeral, patchy, important food resources.

P1-13 IYENGAR, EV*; MEIER, PT; HAMELERS, RE; Muhlenberg College; *iyengar@muhlenberg.edu*

The Small Mammal Project: Engaging Students as Scientists

We describe a collaboration between Muhlenberg Introductory Biology professors and the science librarian on a student-driven, inquiry-based set of activities meant to illuminate the scientific process from the initial scientific questions through to oral dissemination of results. Involving students in hands-on, self-driven investigations will allow them to see the challenges of quantitative scientific investigations, and the role of scientific creativity in experimental design and interpretation. This project allows a large group of students to engage in the type of research project often only available to students working one-on-one with instructors or in research labs. This particular activity requires skeletons of multiple species of small mammals, but there are many ways to alter the project to suit available resources. Students are introduced to scholarly communication in the biological sciences at the beginning of the project, and use this knowledge to identify credible information on the ecology of assigned species of small mammals. The information they find is used to form hypotheses and predictions, which they then test, analyze and present. The project allows students to participate in the scientific process early in their careers, starting with research and hypothesis forming, and ending with presenting their results to their peers. The project helps students to view science as more than merely an accumulation of facts and empowers them to participate in later, more sustained, scientific investigations.

P2-200 JACKSON, BE; Longwood Univ.;
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Effects of large size on 3D flight performance in eastern carpenter bees , Xylocopa virginica

Trade-offs are a powerful tool in investigations of natural selection. Body size may be under intense selective pressure, especially in flying animals, because it offers absolute strength but reduces maneuverability. Eastern carpenter bees (*Xylocopa virginica*) are large, semi-solitary pollinators. They must be small and agile to hover, avoid predators, and defend their nests from conspecifics, yet large and strong to win in frequent intraspecific direct combat. To begin to investigate the effects of size in these bees, I measured performance during aggressive nest-defense flights in Charlottesville, VA, USA. I used three GoPro cameras (120 Hz), wand-calibrated and synchronized using *Argus*, to record over 1300 flight paths from the roughly 20 bees in the colony over two days. I developed a custom Python program using background subtraction and image recognition to automatically produce 3D tracks, which were manually refined. Large size is predicted to reduce hovering ability or peak acceleration. Median flight speed in non-interacting bees was 0.9 ms^{-1}, meaning bees spent significant time at or near hovering. Maximum accelerations regularly exceeded 4*g*, and peaked over 10*g*, when bees were interacting. Compared to existing data on other species, these results suggest that any size-dependent penalty in flight performance may be too small to detect without more direct comparison. Further, some interactions preceding combat occurred at low speeds and accelerations indicating that maximal acceleration may not be a critical factor in such aggression. One potential conclusion is that the strength that comes with increased size outweighs the relatively small flight penalties in this species, and could be a driver behind the evolution of large size in this and other solitary pollinators.

137-3 JACOBS, MW; Project Oceanology;
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Mud, Salt, and Inspiration: Project Oceanology and the Next Generation Science Standards

Since 1972, students at Project Oceanology have been getting their hands wet and their feet muddy while learning about marine science. This type of hands-on education is always valuable and memorable for students, but is it enough? The arrival in Connecticut of the Next Generation Science Standards (NGSS), a new and innovative set of K-12 science education standards, have prompted Project Oceanology to re-evaluate and revise its curriculum for the first time in decades. I'll discuss how we found ways to engage students more deeply in scientific practices and transfer the ownership of the learning process over to the students, even given the logistical constraints of teaching on a working research vessel. I'll also provide a college professor's perspective: what can college-level educators learn from NGSS? How will NGSS change the way incoming college students have been educated, and how could lessons from NGSS be applied in college-level classrooms?

P2-212 JACOBS, C*; HOLZMAN, R; Tel Aviv University, Tel Aviv Israel; *corrinej2@gmail.com*

New Insights Into Power During Pivot Feeding in Syngnathid Fishes

All animals face an overriding constraint on their ability to produce fast movements - muscles contract slowly and over small distances. Repeatedly over evolutionary history, animals have overcome this limitation through the use of power amplification mechanisms. These mechanisms decrease the duration of movement and thereby increase speed and acceleration. The only known example of power amplification in fish is pivot feeding of the Syngnathus family, where fish are able to rotate their head upwards towards the prey at exceptionally high speeds of ~1.5 ms-1. While the mechanism for this movement is understood, our understanding of the effects of power amplification on the magnitude or spatio-temporal patters in the suction flows is limited. Furthermore, it is expected that snout length will affect the flow velocities however, there are no studies quantifying the change in spatial patterns related to snout length. Using a high-speed flow visualization technique, we characterized the spatio-temporal patterns in the flow fields produced during pivot feeding in 4 species of the Syngnathus family with a large variety of snout lengths ranging from 1.7 to 2.6 (ratio of head length to snout length). We found that the power amplification provides 8x greater flow velocities while feeding compared to other teleosts of similar size mouth diameters. We further discuss spatio-temporal changes in suction feeding performance with snout length.

P3-44 JACOBSON, RE*; SILER, EM; MORGAN, JR; IRVINE, SQ; University of Rhode Island, Microtissues Inc.;
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3D Culture of Ciona intestinalis Tissue

Tissue culture is an important tool in biochemistry, cell biology, and cell physiology research. There are currently very few reported cell culture methods in marine invertebrates and even fewer tissue culture lines. We focused on using the model chordate *Ciona intestinalis* to develop tissue culture for the ascidian *Ciona intestinalis*. We used the Microtissues Inc. "3D Petri Dish" system, which consists of cells seeded into agarose microwells, to culture both ovarian and embryonic tissue from *C. intestinalis*. Comparison of the 3D culture and traditional cell culture on treated plastic showed that proliferation was greater and more sustained in the 3D system. This may be due to the 3D system allowing more natural cell-cell interactions. Culture medium was optimized using cell counts over time using different combinations of filtered sea water, deionized water, antibiotic, and growth additives such as fetal bovine serum and *Ciona* hemolymph. It was found that *Ciona* hemolymph was the best growth additive for optimal cell proliferation and is thought to also aid in the protection of the cell culture from protist contaminants that can take over the tissue culture. While the 2D cultures proliferated very slowly, if at all, and were overcome by contaminants, the 3D cultures are still healthy after 6 weeks.

85-1 JACQUEMETTON, CP*; GUPTA, A; HE, C; WARD, AB; MEHTA, RS; University of California, Los Angeles, Harker High School, BASIS Independent Silicon Valley, Adelphi University, University of California, Santa Cruz ; *cjacquem@g.ucla.edu*
Overcoming the Incline: The kinematics of Echidna nebulosa on wet pebble substrate
One of the major morphological changes in the water to land transition is the development of limb-like fins. However, many extant species of fish lacking fins manage to move across a variety of terrestrial substrates. These species are generally described as highly elongate, relying on axial based locomotion to advance their bodies on land. Aquatic animals must overcome an elevation gradient which is inherent to the water to land transition. *Echidna nebulosa*, the snowflake moray, is an eel which occupies both coral reefs and intertidal reef flats. Snowflake morays are known to make terrestrial forays to feed on invertebrates such as crabs. For this study, we tested the hypothesis that incline has an effect on the kinematics of locomotion of *E. nebulosa* when moving across wet pebble substrate. We tested individual eels at two different inclines, 5 and 10 degrees. A level pebble substrate, 0 degrees served as our control. We measured two kinematic variables to determine terrestrial locomotion efficiency: distance ratio, and velocity. Wavelength and amplitude was measured for each wave along the body. Distance ratio and velocity were gathered by tracking three body points (head, center of mass, and tail). When faced with either incline, *E. nebulosa* demonstrated a consistent reduction in velocity and distance ratio while moving across a terrestrial substrate compared to a flat (0 degree) treatment. Differences in kinematic variables between the two incline treatments (5 and 10 degrees) were not significant. Our results show that movement on land for an elongate fish is possible but the real challenge is overcoming the incline to transition from water to land.

P2-128 JAFFE, NJ*; COHEN, CS; San Francisco State University; *njaffe@mail.sfsu.edu*
Comparing Phylogeography of a Direct-Developing Sea Star at Multiple Mites Differentially Affected by Sea Star Wasting Disease
Understanding the interaction between disease epidemics and host population genetic background is critical to predicting impacts and recovery potential. Since 2013, Sea Star Wasting Disease (SSWD) has led to a devastating marine epizootic which has caused drastic declines in many populations of sea stars along the west coast of North America. Among these is the small, six-armed sea star *Leptasterias* spp., which has faced severe but varying impacts as a result of this disease. Unlike larger stars, *Leptasterias* are direct developers and brood live young, which could lead to low gene flow and local differentiation or adaptation, suggesting that differing impacts between sites may have a genetic basis. To investigate the clade composition of sites differentially affected by SSWD, we used DNA sequence from the mitochondrial cytochrome oxidase subunit 1 to barcode 24 *Leptasterias* collected from two sites near Depoe Bay, Oregon. We compared this sequence to DNA sequence from northern California sites showing low disease impacts and central California sites showing strong impacts. At two Oregon sites surveyed here, Boiler Bay and Fogarty's Creek, *Leptasterias* have persisted through SSWD in high abundance. Preliminary results from this study indicate that these Oregon populations show mitochondrial genetic similarity to many populations that have shown considerable decline in central California. These findings suggest that regional variation must be considered along with host mitochondrial clade composition.

S8-7 JAHAN, Israt; FRITZSCH, Bernd*; University of Iowa, Department of Biology; *bernd-fritzsch@uiowa.edu*
Evolving neurosensory cells into the orderly arrangement of the organ of Corti: resolving developmental reorganization of gene expression to guide regeneration.
The mammalian hearing organ is an ordered cellular assembly with orderly innervation: two types of spiral ganglion neurons (SGNs) innervate two types of differentially distributed hair cells (HCs). HCs and SGNs evolved from single neurosensory cells through gene multiplication and diversification. Independent regulation of HCs and neuronal differentiation through expression of basic Helix-loop-Helix transcription factors (bHLH TFs: Atoh1, Neurog1, Neurod1) led to the evolution of vestibular HC assembly and their type of innervation. In mammals, a vestibular organ was transformed into the cochlea with a single row of IHC, three rows of OHCs and peculiar innervation distribution. We will report on Sox2, Foxg1 and Lmx1a mutants that radically alter the OC cell assembly and its innervation and may have driven the evolutionary reorganization. Genetically manipulating the level of bHLH TFs changes HC type and distribution and allows inferences how that transformation might have happened. We will report on how bHLH TFs regulate OHC/IHC and how misexpression (Atoh1-Cre; Atoh1f/kiNeurog1) alters HC fate and supporting cell development. Using mice with altered HC types and distribution, we will demonstrate innervation changes. We will show reorganization of innervation in mouse mutants with selective loss of IHCs. Using these insights, we will speculate on necessary steps to be taken to convert a random mixture of post-mitotic precursors into the orderly OC through spatially and temporally regulated critical bHLH genes.

P2-83 JAHAN, I*; COLOMBO, RE; MAIA, A; Eastern Illinois University; *ijahan@eiu.edu*
Effect of Increased Temperature in Freshwater Fish Energetics
Recent years have shown a rise in mean global temperatures and a shift in the geographical distribution of ectothermic animals. Fish have evolved physiologically to live within a specific range of environmental variation and existence outside of that range can be stressful or fatal. This study investigates physiological processes limiting thermal tolerance, specifically how changes in water temperature affect the swimming muscle mechanics and energetics in largemouth bass (*Micropterus salmoides*) and bluegill sunfish (*Lepomis macrochirus*). We focus on the impact of temperature change at the muscle level in these two species and the capacity to adapt to rapid changes in the environment. Fish were housed at different temperatures (16°C and 20°C) and then tested in a recirculating flow tank 2BL/sec at the opposite temperature. Mass corrected oxygen consumption (MO_2) differed with temperature, with the fish swam at 20°C group having a higher metabolic rate for both species. ANOVA showed that MO_2 was dependent on both species and temperature. Active metabolic rate is 1.2 (in 20°C) and 1.3 (in 16°C) fold higher in largemouth bass than in bluegill sunfish. The Q_{10} calculated at 2 BL/s was 1.43 for bluegill sunfish and 1.57 for largemouth bass which is less than the normal Q_{10} reported for Perciformes of 1.98. At higher temperatures, both species have increased metabolic rates, which will leave fewer resources available for growth and reproduction. Additionally, at higher temperatures oxygen concentrations also tend to be lower, thus increasing the possibility of stress and oxygen being a physiological limiting factor. Freshwater habitats are changing faster than marine habitats and understanding energy requirements of these species will help us improve conservation efforts.

43-4 JAKOBI, TR*; PHILLIPS, N; FINNIS, M; FISHER, A; WATKINS, S; RAVI, S; RMIT, RVC; *timothy.jakobi@rmit.edu.au*
The aerodynamic mechanisms of flapping flight in unsteady air

Foraging insects demonstrate a remarkable ability to overcome the conditions of the atmosphere. Unsteady, gust-ridden air met by flapping flyers demands sharp manoeuvres and fast response times. Bumblebees illustrate the brilliant capacity of flying insects to master this challenge, exhibiting aerial navigation, precise manoeuvrability and load carrying in almost all weather conditions. Recent work has shown that gusts of particular directions can cause a greater disturbance to flight than others. This could be due to the complex interaction between gusts and the unsteady flow structures that characterise flapping flight at this scale. Here, we seek to experimentally uncover the aerodynamic mysteries of flight in gusts by comparing data from live organisms with a representative robotic flapping apparatus. We studied bees flying through identical gusts of different directions and tracked their 3D flight kinematics to characterise the flight responses in conditions typically met in their natural environment. We used a robotic flapper to replicate the conditions encountered by live bees and visualised the flow structures around the flapping wings. We observed that bumblebees flying through upward gusts were affected significantly less severely than those flying through downward gusts. Flow visualisation measurements of our representative flapping wing revealed that the leading-edge vortex (LEV) is weakened in downward gusts, while in upward gusts the LEV is largely unchanged. While bees were severely affected in some gusts, we recorded an interesting sequence of recovery manoeuvres in all gusts, these appearing to serve as useful strategies for minimising the severity of perturbations generated by gusts. These results shed light on an unexplored sector of insect flight aerodynamics and highlight important design aspects for control that could help in shaping the future design of biologically inspired flying robots.

139-3 JAMES, KC*; NATANSON, LJ; Univ. Rhode Island, National Marine Fisheries Service, NEFSC, NOAA; *kjames@uri.edu*
Morphological Variation of Batoid Vertebral Centra and Ramifications for Elasmobranch Age and Growth

Policies guiding sustainable fisheries require accurate estimates of population size and productivity. Age-based characters such as age at sexual maturity and longevity are crucial to correctly determine a population's status and susceptibility to over-exploitation. Vertebral centra are most commonly used to age elasmobranchs because the centra grow in proportion with body size and the number of band pairs (a proxy for age) deposited in the centra increases with time. However, if centra in different positions along the vertebral column deposit material at different rates, then band pair counts will vary within an individual suggesting that deposition may be a result of functional demands, e.g. swimming, rather than age. This study examined centrum morphology and number of band pairs along the vertebral column within individuals, between sexes and size classes (immature, near size-at-maturity, mature) and among five batoid species: little skate, *Leucoraja erinacea*, winter skate, *L. ocellata*, barndoor skate, *Dipturus laevis*, Atlantic stingray, *Dasyatis sabina*, and round stingray, *Urobatis halleri*. Centrum morphology was measured in three directions (dorso-ventral height, medio-lateral width, and rostro-caudal length) for vertebrae 1 through 80 along the column. Band pair counts were made on every 5th vertebrae. Determining the variation in centrum morphology along the vertebral column and through ontogeny is vital for reliable use of vertebral centra for ageing elasmobranchs and thus for assessing population demographics.

98-5 JASINSKI, SE*; CARTER, AM; DODSON, P; University of Pennsylvania; *jasst@sas.upenn.edu*
Significance of the Scapula for Variation and Attachment of Extrinsic and Intrinsic Musculature within Felids (Mammalia: Felidae)

The forelimb morphology of felids (Felidae) correlates with behaviors such as locomotion and prey capture. While the bauplan of felids is conservative, many species differ in the morphology of their scapula. This bone is a pivotal area of attachment for both extrinsic and intrinsic muscles. This may make the scapula an ideal element for predicting locomotor and hunting behaviors of felids. We collected 2D geometric morphometric and measurement data of the scapulae (n=85) of 12 extant genera and 21 species. We tested for differences in scapula morphology by comparing measurement data and using phylogenetically corrected principal components analyses based on a molecular phylogeny. The analyses indicate that semi-arboreal species that exhibit ambush hunting occupy the greatest distribution of morphospace. Some features remain common within the family, such as an enlarged caudal angle for the large m. teres major and enlarged supraglenoid tubercle for a prominent m. biceps brachii. However, the cranial border and the acromion and suprahamate processes show intrafamilial differences. Medium-sized felids show the most variation, and the suprahamate process is the most variable region of the scapula. Some felid clades are highly variable on the medial surface (e.g., *Leopardus* and *Lynx*). The medial surface of *Acinonyx* had the most distinct morphology, separating it from all other species, likely due to its extreme cursorial hunting behavior. Scapular morphology appears to be separating major locomotor groups within Felidae. Many of the differences likely correlate with phylogenetic signal and may indicate these morphologies were established early in the divergence of most major clades. Future inclusion of fossil felids into this dataset should allow for interpretations of possible behavior, biomechanics, and paleobiology.

P1-259 JAYARAM, K.*; SALCEDO, M.; WEAVER, J.; BARTLETT, N.; MAHADEVAN, L.; WOOD, R.J.; Harvard University; *kjayaram@seas.harvard.edu*
Fabrication of insect wings ranging from millimeters to meters

Recent progress in manufacturing has led to rapid rise in the use of physical models for testing hypotheses about the form and function of biological structures. However, natural architectures are often complex structurally and heterogeneous materially making them difficult to manufacture through traditional approaches. One such intricate structure is the wing of an insect which has the added complication of embedded microchannels for fluid flow and gaseous exchange. In this study, we show three fabrication strategies - soft lithography, thermoforming and multi-material 3D printing. for rapidly prototyping wings with high fidelity. We demonstrate each of the above techniques by prototyping wings at 1X (soft lithography), 10X (thermoforming), and 100X (3D printing) scales drawing inspiration from the green darner dragonfly, *Anax junius*, as our model organism. Using these physical models, we test the following hypotheses that, 1) fluid flow within the veins modulates the macro mechanical properties (stiffness, damping) of the wing, and that 2) fluid flow modulated wings affect flight performance. Our preliminary experiments reveal that fluid flow can play a major role in modulating the stiffness and damping of the wing. We are currently performing complementary experiments on biological samples to measure the range of flow rates and their scaling with size. As our next steps, we aim to build experiment setups to test the flapping performance of the robotics prototypes across the biologically relevant range of frequencies in our custom wind tunnel. We believe that such high fidelity physical models are critical to revealing novel insights into the functional morphology and biomechanics of complex biology structures by serving as faithful test platforms for hypotheses testing.

78-6 JAYNE, BC*; VORIS, HK; NG, PKL; University of Cincinnati , Field Museum of Natural History, Chicago, National University of Singapore; *bruce.jayne@uc.edu*

How Big is too Big? Using Crustacean-eating Snakes to Test How Anatomy and Behavior Affect Prey Size and Feeding Performance

The evolutionary innovations that allow snakes to swallow large prey whole provide a model system for testing how anatomy constrains what predators eat. Several of the specializations in the dentition and cranial anatomy that facilitate snagging prey and swallowing large meals whole, however, seem maladaptive for functions such as taking bites or consuming hard-bodied prey. In this study, for a clade of three species of homalopsid snakes with the unusual diet of decapod crustaceans, we quantified maximal gape, prey size, and feeding behavior. *Fordonia leucobalia* eats hard-shelled crabs and had maximal gape similar to a piscivorous relative (*Cerberus schneiderii*). *Gerarda prevostiana* and *Cantoria violacea* eat freshly molted crabs and snapping shrimps, respectively, and their maximal gapes were significantly smaller than those of both *F. leucobalia* and *C. schneiderii*. The rank order of species from smallest to largest relative sizes of prey consumed in nature was *F. leucobalia*, *C. violacea* and *G. prevostiana*. Unusual specialized feeding behaviors included: 1) a closed-mouth strike and using the chin to initially pin down the crabs (*F. leucobalia*), 2) breaking off the crab legs (*F. leucobalia, G. prevostiana*), and 3) ripping apart the crab carapace aided by coils of the body (*G. prevostiana*). Behavioral innovations and choice of prey allowed *G. prevostiana* to readily consume crabs 2-4x larger than their maximal gape area, and they had prey handling times approximately 9x faster than those of *F. leucobalia* consuming prey of similar relative size. This is a striking example of how the evolution of specialized behaviors can improve performance and circumvent the anatomical constraints on prey size.

3-2 JELLISON, BM*; GAYLORD, B; University of California, Davis; *bmjellison@ucdavis.edu*

Population-Level Variation in Behavioral Tolerance of Intertidal Snails to Ocean Acidification

Human-induced changes in seawater chemistry, including reductions in pH (‘ocean acidification,' OA), are known to induce both mechanical and physiological costs for many marine organisms, and emerging evidence suggests that reduced pH can also disrupt an organism's behavior. While such behavioral changes have the potential to influence a variety of species interactions (e.g., avoidance responses of prey to predators), the nature and strength of OA-induced behavioral shifts may also depend on the evolutionary histories of exposure of vulnerable taxa to low pH. Here we investigated impacts of ocean acidification on the antipredator, "crawl out" behavior of two geographically separated populations of intertidal turban snails (*Tegula funebralis*) as induced by chemical cues from the predatory sea star, *Pisaster ochraceus*. We found that low seawater pH attenuated the archetypal crawl out responses of snails, but that the behavioral impairment of snails also varied with site of origin. The percentage of time that fleeing snails spent out of the water, in refuge from predation, decreased with declining pH in turban snails sourced from a region exposed to strong upwelling (Bodega Bay, CA), where seawater pH is routinely lower. In contrast, snails that originated from a region of more benign pH conditions (San Diego, CA) maintained a robust response to predator cue regardless of seawater pH. Although OA is expected to pose a major threat to marine species, our work suggests that geographic variation in tolerance to reductions in pH may play an important role in determining population responses to future conditions.

P1-96 JEONG, N*; MECKFESSEL, N; STAHLSCHMIDT, Z.R.; Univ. of the Pacific; *n_jeong@u.pacific.edu*

Is the tradeoff between reproduction and locomotion plastic in response to oxidative stress and food limitation?

Animals are under selection to optimize several traits associated with fitness, such as reproduction, growth, and self-maintenance. However, a tradeoff among two traits often occurs wherein an animal invests into one trait at the expense of investment into another trait. Such two-trait tradeoffs may be fixed, but they may also be plastic in response to the environment (e.g., a tradeoff only occurs when food becomes less available) or due to investment into a third trait. We investigated these dynamics in female sand field crickets (*Gryllus firmus*), which exhibit a wing polymorphism that mediates a flight-fecundity tradeoff. During early adulthood, short-winged (SW) females prioritize egg production (fecundity) over locomotion or dispersal (flight) capability while long-winged (LW) females invest in flight musculature at the expense of fecundity. We used a 2 x 2 factorial design to manipulate food availability (unlimited or limited access to cat food) and investment into antioxidant defenses (repeated injection of the oxidative stressor, paraquat, or a sham injection) for SW and LW females during early adulthood. We measured the following traits: body size and condition (femur length and scaled mass index, respectively), and investment into fecundity (dry ovary mass) and flight (status of the dorso-longitudinal muscles). Preliminary results in LW females indicate that oxidative stress and food limitation shift the flight-fecundity tradeoff in different directions: oxidative stress reduces investment into flight musculature while food limitation reduces investment into ovary mass. Complete results from our study will inform the dynamics by which animals balance multiple important, widespread traits (reproduction, locomotion, and self-maintenance) in variable environments.

S9-5 JIMENEZ, Ana; Colgate University; *ajimenez@colgate.edu*

'The same thing that makes you live can kill you in the end': exploring the effects of growth rates and longevity on cellular metabolic rates and oxidative stress.

All aerobic organisms are subjected to metabolic by-products known as reactive species (RS). RS can wreak havoc on macromolecules such as structurally altering proteins and inducing mutations in DNA, among others. To combat accumulating damage, organisms have an antioxidant system to sequester RS before they cause cellular damage. The balance between RS production, antioxidant defenses, and accumulated cellular damage is termed oxidative stress. Physiological ecologists, gerontologists and metabolic biochemists have turned their attention to whether oxidative stress is the principal, generalized mechanism that mediates and limits longevity, growth rates and other life-history trade-offs in animals, as may be the case in mammals and birds. At the crux of this theory lies the regulation and activities of the mitochondria with respect to the organism and its metabolic rate. At the whole-animal level, evolutionary theory suggests that developmental trajectories and growth rates can shape the onset and rate of aging. Mitochondrial function is important for aging since it is the main source of energy in cells, and the main source of RS. Altering oxidative stress levels, either increases in oxidative damage or reduction in antioxidants, has proven to also decrease growth rates, which implies that oxidative stress is a cost of, as well as a constraint on, growth. Yet, in nature, many animals exhibit fast growth rates that lead to higher loads of oxidative stress, which are often linked to shorter lifespans. In this review, I summarize the latest findings on whole-animal life history trade-offs, such as growth rates and longevity, and how these can be affected by mitochondrial cellular metabolism, oxidative stress, and I will highlight any mito-nuclear interactions within cells that may also affect longevity and growth rates.

P1-228 JIMENEZ PADILLA, Y*; LACHANCE, M-A; SINCLAIR, BJ; University of Western Ontario, London, Canada; *yjimenez@uwo.ca*

Live Yeasts Determine development Time in Drosophila melanogaster

The gut of insects is host to bacteria, archaea, fungi, protozoans and viruses, and together they affect host physiology. Most studies have focused on the bacterial microbiota, but little is known about the other members of the gut flora. The gut microbiota of *Drosophila melanogaster* is relatively simple, and its bacteria and yeast species have been characterized, thus making it a useful system for understanding the role of yeasts in insect physiology. Yeasts are usually regarded as a food source; however, here we show that the effect of yeasts on *D. melanogaster* development is not solely explained by the nutritional content of the yeast. To investigate the effect of yeast on *Drosophila* development time, we started by rearing the flies either as axenic (free of microbes), or gnotobiotic (with a known yeast species in their gut), and recorded the pupation and eclosion times. We used two species of yeast, *Saccharomyces cerevisiae*, which is commonly used in lab settings and *Lachancea kluyveri*, which can be recovered from the gut of some wild caught *Drosophila* species. Both yeasts reduce development time equally, and the biggest effect is observed when the yeast is alive (gnotobiotic flies). While heat-killed yeast and nutritional supplements reduce the development time in axenic flies, they do not replicate the effect of live yeasts.

P2-232 JINDRICH, DL*; QIAO, M; California State University San Marcos, University of North Carolina at Chapel Hill; *djindrich@csusm.edu*

Quantifying Joint Function Using Mechanical Analogs: Strut, Motor, Spring and Damper

Functional differences among joints may help to coordinate overall leg function during locomotion. Legs have been hypothesized to exhibit a proximal-distal gradient in joint mechanical function: from power production at the hip to spring-like behavior at the ankle. However, potentially distinct joint functions must sum together to result in the overall spring-like function of legs during running and strut-like function of legs during walking. We tested the hypothesis that individual leg joints exhibit functional differences during both walking and running. We developed quantitative indices that characterize joint energy management based on mechanical analogs: strut, motor, spring, and damper. The strut index is the dimensionless ratio between the power and moment. The motor, spring and damper indices characterize the nature of mechanical joint work: energy production, absorption followed by production, and absorption, respectively. Consistent with our hypothesis, in humans the hip acts as a motor, the knee as a damper, and the ankle as a spring during running. During walking, knee function becomes more complex, but the hip remains motor-like and the ankle remains spring-like. Leg joint function was consistent with a proximal-distal gradient. Understanding the contribution of differential joint function to overall leg and body mechanics is an important neuromechanical question with potential implications for understanding morphology, scaling, and evolution. Moreover, the indices we developed could be useful for quantitatively understanding function in many contexts, including for muscles and other tissues.

51-5 JOHNSEN, S*; OSBORN, KJ; THOMAS, KN; ROBISON, BH; Duke Univ., Smithsonian Inst., Duke. Univ., MBARI; *sjohnsen@duke.edu*

From the Moon in the Sky to the Deep Blue Sea: Using Lunar Optics to Understand the Blackness of Mesopelagic Fish

Although color is increasingly studied in both animals and plants, black is often overlooked, even though it can serve important functions. In the case of deep-sea fish, black surfaces strongly absorb (and thus do not reflect) the bioluminescent searchlights of predators, therefore providing a form of camouflage. So, it is perhaps not surprising that many deep-sea fish appear to be exceptionally black. We investigated this in several species of mesopelagic fish in three ways: 1) reflectance spectroscopy 2) scanning and transmission electron microscopy, and 3) optical modeling. The spectroscopy showed that many species reflected very little light, in some cases less than 0.5%, which is one tenth of that seen in most black surfaces found in normal human experience. Interestingly, even though the reflectances were already quite low, they were generally lower in the blue-green portion of the spectrum that comprises bioluminescence, suggesting further optimization. The microscopial studies showed that the surfaces of the black fishes were quite complex. In addition, many had thick sub-epithelial layers of close-random-packed spheroidal melanin granules that were approximately 0.4 to 0.8 microns in diameter. Using methods developed for understanding the reflective properties of lunar soil, which is similarly composed of close-packed strongly absorbing spheroidal particles with high refractive index, we found that the melanin granules found in the black fish were the optimal size for achieving the greatest absorption of incident light with the least amount of material. Together, this study highlights the importance of blackness to deep-sea fish and the strong evolutionary pressures for camouflage in even this dark environment.

33-3 JOHNSON, KE*; CLARK, CJ; University of California, Riverside; *kjohn005@ucr.edu*

Vocal Learning in the Costa's Hummingbird

Hummingbirds, like songbirds, are thought to be vocal learners. However, our understanding of vocal learning in hummingbirds is still in its early stages. Because of the independent evolutionary origins of vocal learning in hummingbirds, what we know of songbirds may not be applicable to hummingbirds. In a previous study, I found that Costa's hummingbirds (*Calypte costae*) require a live adult tutor in order for vocal learning to take place in a lab setting. It was also found that Costa's hummingbirds are capable of learning songs similar to their species-specific song but unable to learn the song of their sister's species, the Anna's hummingbird. In two follow-up experiments on open-ended learning and the sensitive phase of learning were examined. Costa's hummingbirds, from a previous isolation experiment, were moved from acoustic isolation to an outdoor aviary where the birds were exposed both acoustically and visually to other hummingbirds and other species of birds. The songs of the birds were periodically recorded and examined to see if their song stayed the same or changed post exposure to other birds. To examine the sensitive phase of vocal learning, young male Costa's were taken into captivity and reared in a controlled acoustic environment. The young males were tutored at two different periods of time, the first group received "early" tutoring from day 35 to 65 post-hatch and the second group received "late" tutoring from day 75 to 105 post-hatch. The birds were tracked and then their song ontogeny was monitored. These two experiments so far have shown that Costa's hummingbirds are in fact open-ended learners, and that the sensitive phase of learning may in fact extend throughout both the early and late tutoring periods. Future experiments are necessary to define when the sensitive period of learning is for the Costa's hummingbird.

102-7 JOHNSON, D.*; STAHLSCHMIDT, Z.R.; Univ. of the Pacific; *d_johnson23@u.pacific.edu*

City limits: Determinants of thermal maxima in an urban ant community

Examining the thermal responses of urban animals is critical because cities are rapidly expanding, and temperatures are increasing globally—particularly in urban environments. Although cities tend to be warmer due to the heat island effect, this thermal hazard may be offset by increased availability of water in urban ecosystems (e.g., irrigation). The sensitivity of animals (including those in urban environments) to high temperatures can be determined by the critical thermal maximum (T_{max}), and variation in T_{max} may be driven by a range of factors. For example, animals that are larger, adapted to warmer microclimates, or well-hydrated may have relatively high T_{max} values. Alternatively, T_{max} may be phylogenetically constrained wherein closely related species exhibit similar T_{max} values, regardless of differences in morphology or physiological state. Thus, we manipulated water access and determined T_{max} (knockdown temperature) for ants common to cities in California's Central Valley. We determined T_{max} (range: 29-61°C) for 688 individuals spanning 11 species. We will discuss the effects of body size, hydration state, and adaptation to local environments (active temperatures of ants in the field) on T_{max} after controlling for phylogeny. Together, our results will inform the abiotic and biotic factors influencing animals' sensitivity to high temperatures in an increasingly warm world.

S6-1 JOHNSON, MA*; HUSAK, JF; VITOUSEK, MN; KNAPP, R; HORMONEBASE CONSORTIUM, ; Trinity University, University of St. Thomas, Cornell University , University of Oklahoma, www.hormonebase.org; *mjohnso9@trinity.edu*

The Evolution of Endocrine System Variation: A Large-Scale Comparative Analysis of Androgens

Hormones play a central role in coordinating behavior and physiology, responding to changes in the environment, and promoting transitions among stages of the life cycle. Despite their importance, and the large amount of available data on circulating hormone levels, we still know remarkably little about how and why circulating hormone levels differ. Hormone concentrations show striking variability at all taxonomic scales, but to test large-scale hypotheses on hormonal evolution, a comprehensive database of hormonal data is needed. Here, we introduce HormoneBase, a publicly-available database of published measures of testosterone, 11-ketotestosterone, corticosterone, and cortisol in free-living, adult vertebrates. HormoneBase includes over 6,300 measures of hormones from 431 species, reported in 658 publications from 1967 to 2015. Using this database, we test for abiotic and biotic predictors of mean testosterone or 11-ketotesosterone levels, as well as variability in hormone levels, across all vertebrate groups: fishes, amphibians, reptiles, birds, and mammals. Variables include latitude, elevation, and breeding season length, as well as numerous life-history and social-organization variables. We also looked specifically within fishes to determine if patterns were similar when considering 11-ketotestosterone. Finally, we determined whether baseline glucocorticoid levels were related to androgen levels across vertebrates. While these analyses have been performed in specific taxonomic groups separately, our analyses represent the first vertebrate-wide analysis of androgen levels and provide important insight into the evolution of vertebrate endocrine function.

P1-54 JOHNSON, S.*; KROHMER, R.W.; Saint Xavier University, Saint Xavioer University; *johnson.s12@mymail.sxu.edu*

Effect of Sex Steroid Hormones on Neurogenesis in the Injured Red-Sided Garter Snake Brain

Injury to the homeotherm brain results in the upregulation of the estrogen-synthesizing enzyme aromatase. While peripheral estrogens have been shown to be neurogenic in birds and mammals, the possible effect of sex steroid hormones on the injured reptilian brain has not been examined. To determine whether or not injury-induced aromatization and or, local estrogen provision can affect neurogenesis following mechanical brain damage, adult male red-sided garter snakes (*Thamnophis sirtalis parietalis*) were castrated and implanted with either an empty silastic tube (control) or an individual or combination of tubes containing testosterone or estradiol. Fourteen days after implantation, animals were given a unilateral penetrating brain injury. All animals were then injected with the thymidine analog 5-Bromo-2'-deoxyuridine (BrdU) on the following schedule: immediately following surgery, 24 hours after surgery and 24 hours prior to perfusion. Animals were perfused 96 hours after lesions were administered, cryoprotected overnight, snap frozen on dry ice and sectioned on a cryostat in the coronal plane. Tissues were visualized using an antibody against BrdU. Sections containing the injury site and surrounding areas (III ventricle and preoptic area (POA) were examined for neurogenesis. The relative density of BrdU positive cells for each of the treatment groups was assessed and their locations recorded.

S4-3 JOHNSON, KR; Smithsonian National Museum of Natural History; *johnsonkr@si.edu*

Fossils, Lost Worlds, and the Hero's Journey

Fossils are exquisite objects but they are also fragments of very ancient stories, and paleontologists are time travelers on planet earth. I became a paleontologist to explore these lost worlds. But "fossil" can also be a derogatory term and many people I met were bored by rocks. So I began to watch people to see how they responded when described what I was seeing. Using their cues, I learned I could make fossils funny or describe geology in terms of food without losing the thread of insight. I began to write like I spoke. I also learned to search for a place of common understanding, spending time to locate my audience where they were before I began to tell them my story. Look at your audience, respect them, and look for what makes them smile. I'm from the west coast and have always been frustrated with its meager offering of publically available paleontology. In 1998, I began to travel with artist Ray Troll in search of fossils, rock shops and museums, and to meet the people who found fossils and worked at rock shops and museums. We spent the last decade searching for the remains of the prehistoric Pacific. In California, we encountered the much-told tale of John Steinbeck and Ed Ricketts. Their friendship and travels together as a writer and an ecologist resonate deeply with those who are inspired by the beauty and meaning of language and ecology. In Washington, we found the Western Flyer, the fishing boat that carried them to the Sea of Cortez and were bowled away by the power of an iconic artifact. In Alaska, we learned of Ricketts' less-well-known 1933 trip with Joseph Campbell who was forming his views of mythology by communing with scientists. And we found a ton of fossils. Scientific storytelling is presently undergoing a golden age as we realize how important narrative, imagery, objects, humor, and surprise are to the absorption of meaning.

124-2 JOHNSON, AB; LAMBERT, JD*; Univ. of Rochester; *dlamber2@mail.rochester.edu*

Elongating animal body plans: the role of Notch/delta signaling in mollusc posterior growth

In many animal groups the anterior develops first, and the body elongates progressively by growth at the posterior pole. This may have been present in the last common ancestor of bilaterians, but the diversity of extant mechanisms has made this difficult to support. So far most attempts to find molecular similarities between posterior growth in vertebrates and other animals have focused on somitogenesis/segmentation processes. There are a few commonalities, but overall little molecular similarity has been found. We propose that teloblastic growth—where elongation occurs by production of a band of progeny cells from a set of posterior stem cells—may be a more deeply conserved mode of posterior growth in animals. The Notch/dl signaling pathway is a potential point of similarity between different taxa with teloblastic growth, and other forms of posterior growth. In the model mollusc *Ilyanassa*, we have found that N/dl signaling is required for pattering the 4d teloblastic lineage, a broadly conserved aspect of spiralian development. First, we show that delta and Su(H) are specifically expressed in a subset of cells in and around the 4d lineage. We then demonstrate using specific gene knockdowns, that loss of either delta or notch activity in the whole embryo, or specifically in the 4d lineage, prevents the differentiation of all structures derived from 4d. In ongoing work, we are examining the role of N/dl signaling relative to other factors that are required in this lineage, including Nanos, dpp, retinoic acid and caudal-like. These results establish N/dl as a key regulator of teloblastic growth in a mollusc. Together with existing pharmacological results from leech, we argue that the role of this pathway in teloblastic growth is a conserved aspect of spiralian development, and may hint at posterior growth mechanisms that are conserved between more distantly related groups of animals.

123-2 JOHNSON, GR; DONOVAN-MAIYE, R; MALECKAR, MM; WILLIAMS, CD*; Allen Institute for Cell Science; *mollym@alleninstitute.org*

A novel conditional model of cell organization: building an integrated cell

A central biological principle is that cellular organization is strongly related to function. However, determining cellular organization is challenged by the multitude of different molecular complexes and organelles that comprise living cells and drive their behaviors. Currently, the experimental state-of-the-art for live cell imaging is limited to the simultaneous visualization of only a limited number (2-6) of tagged molecules. Modeling approaches can address this limitation by integrating subcellular structure data from diverse experiments. Generative models are useful in this context. They capture variation in a population and encode it as a probability distribution, accounting for the relationships among structures. However, these models suffer limitations, including dependence on preprocessing methods and limitations with respect to structures that vary widely in localization (diffuse proteins). Recent advances in adversarial networks ("deep learning") are relevant to our problem. We present here a non-parametric (conditional generative) model of cell shape and nuclear shape and location, and relate it to the variation of other subcellular structures learned from live-cell, 3D microscopy images of our hIPSCs, gene edited with fluorescent reporters for the structure of interest. The model is trained on datasets of 100s-1000s of these fluorescence images and accounts for the spatial relationships among the intracellular structures of interest, their fluorescent intensities, and generalizes well to a variety of localization patterns. Using these relationships, the model allows us to predict the outcome of unobserved experiments, as well as encode complex image distributions into a low dimensional, probabilistic representation. This latent space serves as a compact coordinate system to explore variation.

P3-116 JONES, TK*; CONNER, WE; Wake Forest University; *jonet15@wfu.edu*

Active acoustic interference elicits echolocation changes in heterospecific bats

Echolocating bats rarely forage in isolation and the presence of both conspecific and heterospecific individuals have the potential to produce acoustic interference. Recent studies have shown that at least one bat species, the Brazilian free-tailed bat (*Tadarida brasiliensis*), produces specialized social signals that disrupt the sonar of conspecific competitors. We discuss the differences between passive and active jamming signals and whether heterospecific jamming occurs in species overlapping spatiotemporally as well as whether such interference elicits a jamming avoidance response (JAR). We compare the capture rates of tethered moths and the echolocation parameters of big brown bats (*Eptesicus fuscus*) challenged with the playback of the jamming signal normally produced by Brazilian free-tailed bats and playback of modified versions of this signal. There were no differences in the capture rates of targets with and without the jamming signal though significant changes in both spectral and temporal features of the bats' echolocation were observed. Flexibility in echolocation is an important characteristic for overcoming various forms of acoustic interference and may serve a purpose in interspecific interactions as well as intraspecific ones.

P3-253 JONES, DG*; HAZARD, LC; Montclair State Univ., New Jersey; *jonesd26@mail.montclair.edu*

Salinity Aversion in Adult and Larval Wood Frogs

Amphibians are highly vulnerable to aquatic pollutants due to the permeability of their skin; gilled aquatic larvae may be especially susceptible. Behavioral avoidance of pollutants could mitigate the effects of exposure. Increasing application of road deicers for travel safety has led to elevated sodium chloride levels in some temperate forest wetlands. The physiological effects of road deicers on amphibians are well known, and include reduced breeding success, morphological abnormalities, and even mortality. However, less is known about the behavioral responses of adult and especially larval amphibians to increased environmental salinity. In this study, the behavioral responses of both adult and larval Wood Frogs, *Lithobates sylvaticus*, to increased salinity were studied via salinity choice trials. For both adults and tadpoles, time spent in salt solutions decreased with increasing salinity. The threshold for response was approximately 0.15 M (slightly hyperosmotic). Habitat selection by tadpoles has been linked to temperature, substrate, and other factors, but salinity avoidance has not been previously reported. Since increased salinity has been associated with decreased fitness, behavioral avoidance of high salinity and preference for lower saline systems could be advantageous for Wood Frogs, giving adults the potential to select breeding sites with lower solute levels and tadpoles the potential to select appropriate microhabitats within a vernal pool.

88-2 JONES, AJ*; BOURDEAU, PE; Humboldt State University, Arcata; *angela.jones@humboldt.edu*

Morphological Variation in Aboral Spines in the Forcipulate Sea Star, Pisaster ochraceus, Across Developmental and Environmental Gradients

In Echinodermata, aboral spines have many different functions. Certain spines in Ophiuroidea have been modified to function as lenses, whereas urchin spines may be used for protection and even locomotion. Previous work on fossil echinoderms suggests that aboral spines can function as a second test to combat wave forces and to create a boundary layer for respiration. These morphological assumptions are presumed of echinoid-like anatomy. To date, there has been little research on asteroid spine morphology and within-species variation across environmental gradients. *Pisaster ochraceus* is a forcipulate sea star that resides in a variety of habitats from wave-exposed rocky intertidal zones of the open coast to wave-protected embayments. Here I describe distinct variation in aboral spine density and morphology in *P. ochraceus* across developmental, seasonal, and spatial environmental gradients using scanning electron microscopy. *P. ochraceus* aboral spine density was significantly higher in stars at wave-exposed sites and during winter, when wave force is maximal. Results also indicate that aboral spine microstructural variation also varies according to habitat type. Spines from stars in wave-protected habitats were often larger with spine heads lacking lateral protrusions and contained smaller spinelets than those in wave-exposed counterparts. Laboratory studies are being conducted to determine whether the observed variation in aboral spines reflects phenotypic plasticity in star body shape via the uptake or discharge of seawater in response to short-term variation in flow conditions, or a longer-term developmental response by juveniles to varying flow conditions.

P1-82 JONES, MM*; NUNEZ, CMV; Iowa State University; *jonesm@iastate.edu*

Indirect Effects of Immunocontraception on Male Aggression and Stress in Feral Horses

In social species like the feral horse (*Equus caballus*), changes in individual behavior are likely to impact associated animals. On Shackleford Banks, NC, mares treated with the contraceptive agent porcine zona pellucida (PZP) demonstrate decreased fidelity to their band stallions. The potential impact of these PZP-related changes in female behavior on male behavior and physiology remains largely unexplored. We compared the frequency of male-male contests and physiological stress, measured by fecal cortisol levels, for males that had varying levels of experience with mare group changing behavior. Our data suggest that female group changing behavior does impact male fighting and cortisol levels, and these impacts may vary depending on home range ecology. In the East, a more open landscape with a history of territoriality, males associating with changing females fought more often. Conversely, in the West, where high dunes and dense brush limit visibility and horses share resources, female group changes seem to have no effect on male fighting. Across regions, males who experienced three group changes by females in a two week period exhibited increased cortisol levels during this time compared to stallions experiencing one or zero group changes. Further investigation of such behavioral and physiological effects will improve our understanding of the consequences of immunocontraception management for non-target animals.

17-7 JONES, BC*; DUVAL, EH; Florida State University; *jonesbc@gmail.com*

El Niño mediates a tradeoff between growth rate and insect-induced lesions in lance-tailed manakin (Chiroxiphia lanceolata) nestlings.

Growth rate can affect survival. For example, in tropical birds, growth rate is an important determinant of fledge timing. Fledging sooner limits time in the vulnerable nestling stage, and thus increases survival likelihood. Growth rate is influenced by environmental factors, such as quality of parental care, food availability, disease, and local weather conditions. However, few have investigated the possible effects of global climate phenomena on the growth rate of animals. The El Niño/southern Oscillation (ENSO) is one such global climate pattern characterized by warming of the tropical Pacific. The ENSO can affect primary production and population size of at least some species. We take the logical next step to determine if growth rate and survival is influenced by the ENSO. From 2007 to 2017 we measured the growth of 734 lance-tailed manakin (*Chiroxiphia lanceolata*) chicks throughout the nestling phase and estimated average yearly growth rate. We found that during years of higher El Niño activity nestlings grew significantly slower. Counterintuitively, more severe El Niño years correlated with drier conditions at our field site in south central Panama. We also found a significant negative correlation between El Niño intensity and the occurrence of insect-induced lesions. That is, during breeding seasons of heavier than average rain fall, nestlings grew faster, but developed sores more often, presumably because of increased populations of predatory insects in those years. Neither ENSO nor chick growth rates were related to chick recruitment. Enhanced growth rates in years of lower El Nino intensity are accompanied by a tradeoff from increased exposure to predatory insects, which may explain the lack of a relationship between growth rate and survival.

40-1 JONGSMA, G.F.M.*; PORTIK, D.M.; LEACHÉ, A.D; FUJITA, M.K.; Florida Museum of Natural History, University of Florida, University of Texas at Arlington, Burke Museum of Natural History and Culture, University of Washington; *gregor.jongsma@gmail.com*

Comparative Phylogeography of Amnirana (White-lipped Frogs) at Historical Refugia across the Upper and Lower Guinean Forests, Africa

The Upper and Lower Guinean Forests host the highest levels of biodiversity on the African continent. There is increasing support for the role that historical forest refugia play in generating and maintaining diversity in the Afrotropics. The Forest Refuge Hypothesis (FRH) posits that repeated forest contraction and expansion events in the tropics have driven allopatric speciation, effectively serving as "species-pumps." We focus on multiple species of the genus *Amnirana* that are co-distributed across several historical forest refugia in the Upper and Lower Guinean Forest Zones. Preliminary multi-locus sequence data supports that there are high levels of cryptic diversity within this genus, much of which is associated with predicted forest refugia within the Guinean forests of West and Central Africa. However, since this support is only correlative we wanted to more stringently test the FRH using historical population demographics of several co-distributed members of *Amnirana*. Taking a comparative phylogeographic approach we collected ddRADseq data for 254 individuals across 19 countries. We predict that populations at forest refugia will have a signal of population stability and that between refugia populations will have signals of expansion. Taking a comparative phylogeographic approach is powerful for teasing apart shared historical processes from idiosyncratic responses of individual species.

139-5 JORDAN, P.; KENALEY, C. P.*; Boston College; *cpkenaley@gmail.com*

Body-Size Evolution in Ray-finned Fishes (Actinopterygii): Tempo, Mode, and Ecological Correlates

Body size features prominently in nearly every aspect of organism's biology, including several fitness-related parameters such as fecundity, mating success, energy budget, and life span. Thus, explorations of macroevolutionary trends associated with the tempo and mode of size-evolution are important in understanding the diversity of size in ray-finned fishes. Here we use body length data from 1,400 species of extant actinopterygians and the most current and expansive multi-locus phylogeny for the group to evaluate a multitude of models of log-transformed body-length evolution. We found that the tempo of size evolution in ray-finned fishes is explain best by an Ornstein-Uhlenbeck (OU) process, thereby suggesting that size evolves toward a phenotypic optimal value. In addition, to assess which ecological parameters may contribute to size diversity, we gathered distribution and habitat data for all of our included species. Using phylogenetic generalized least squares analysis under both OU and Brownian motion error models, we found that depth and ecoregion explain 60% of the variation in body length. Together, these results suggest that the evolution of body size is influenced by the ecophysiological constraints of habitat preference.

P1-277 JORGE, J.*; KUMAR, A.; SUTTON, G. ; PATEK, S. N.; Duke, Panther Creek H.S., U. Bristol; *jjorge@berkeley.edu*

Tick-Tock Tiny Impacts: A Novel Pendulum Mechanism for Measuring the Energetics of Trap-Jaw Ant Strikes

Trap-jaw ants close their mandibles with extraordinary accelerations and generate impact forces that exceed their body weight by two orders of magnitude. They use their mandibles to strike prey and intruders, and to catapult themselves through the air to escape potential threats. The strikes have an initial energy budget set by musculature and an elastic exoskeleton, yet the energetic efficiency of these strikes as they interact with targets is presently unknown. The extreme accelerations of tiny structures present challenges to characterizing the energetics of impacts, because of their transient strike durations and high peak forces. We examine the impact dynamics of trap-jaw mandibles and their targets using a novel pendulum setup. We measured energy transfer between the trap-jaw ant *Odontomachus brunneus* (Ponerinae) and its target during a mandible strike. A plastic bead (11.5 mg) and an ant (4-6 mg) were each attached to a thin strand to form two separate pendulums. The paths of both the ant and the bead after the impact were recorded with high speed imaging (12500 fps). Kinetic energy of both the bead and ant was then calculated. We found considerable variance in the total post-strike kinetic energy (kinetic energy of the bead plus that of the ant). The kinetic energy of the ant after the mandible strike ranged over two orders of magnitude (average 0.78 μJ) as did the bead's kinetic energy (average 0.38 μJ). We then divided the total post-strike kinetic energy by the kinetic energy of the closing mandibles to calculate the efficiency of energy transfer which averaged 7%. This study offers new insights into the methods for study tiny impacts and the potentially low efficiency of energy transfer during tiny, high acceleration impacts.

P2-22 JOSEFSON, CC*; SIRMAN, AE; HOOD, WR; Auburn University, North Dakota State University; *ccj0011@auburn.edu*

The role of maternal protein intake on partitioning of resources among offspring

Life history theory states that mothers should optimize their reproductive success by allocating resources in a way that will result in the greatest fitness, given their environment. Therefore, under this hypothesis, differences in maternal diet should manifest in a manifest in differential resource allocation during a reproductive bout. Here, we aim to examine the effects of maternal diet (protein composition) on resource partitioning among offspring in wild-derived house mice (*Mus musculus*) housed in semi-natural enclosures. In this study, the mice were randomly assigned at weaning to groups that were given ad lib access to a high (20%) or low (10%) isocaloric protein diet. The diets were also similar in the concentration of fat, fiber, minerals, and vitamins. We predict that individuals on a low-protein diet will have a sex-ratio significantly different from the expected 1:1, and that they will produce more female offspring. We also predicted that mothers in the low-protein group will invest less in offspring production, which will manifest in either a decrease in offspring number and/or a decrease in litter mass. These results will inform us on the impact of maternal protein intake on offspring phenotypes.

82-1 JOSEFSON, CC*; HOOD, WR; Auburn University; *ccj0011@auburn.edu*

Life history trait co-variation patterns within the house mouse (Mus musculus) differ from across species predictions

The idea that traits which increase fecundity necessarily trade off with other traits is a central tenet of life history theory. Previous work exploring these trade offs across species of mammals supports this idea, however, studies investigating relationships among life history traits (e.g., fecundity, longevity, and metabolic traits) does not always support these trade offs within species. We obtained data from the publicly available Mouse Phenome Database by the Jackson Laboratory to investigate correlations among life history traits and between life history and metabolic variables in adult female mice. We collapsed fitness-related variables in a principal component analysis, which resulted in two principal components (breeding frequency and reproductive strategy) that describe the variance in reproductive traits. Scores from this PCA were then regressed against measurements from other phenotypic traits (e.g., mass-specific metabolic traits, longevity, and body size). Although these strains are typically used in biomedical research models, we propose that data from lab mice can be used to identify patterns across life-history variables that could not otherwise be studied in wild rodents. Our findings support the ideas that 1) traits that increase reproductive performance do not always come at a cost to other life history traits, such as longevity, and 2) patterns of life history trait co-variation within species is not always consistent with predictions that are based on interspecific comparisons. Together, these findings outline the need to continue studying patterns within species, as they may differ from initial predictions.

57-2 JUDSON, JM*; BRONIKOWSKI, AM; JANZEN, FJ; Iowa State University; *jjudson@iastate.edu*

Population Genetic Structure in a Widespread Reptile, the Painted Turtle (Chrysemys picta)

In wide-ranging species, such as the painted turtle, population genetic structure is anticipated due to limitations on dispersal, particularly in conjunction with local adaptation. However, turtles evolve slowly relative to other lineages, and the painted turtle expressed little genetic variation across its entire range in a previous study. We tested the hypothesis that painted turtles exhibit population genetic structure across the range west of the Mississippi River, an area encompassing enormous temperature and precipitation gradients, using a GBS approach. We sequenced tissue samples from 172 individuals representing seven populations spanning the western range of the painted turtle (northwestern border of Illinois, northern Minnesota, central Kansas, western Nebraska, southern New Mexico, northern Idaho, and northwestern Oregon) and processed SNPs according to GATK Best Practices. We assessed putatively neutral population genetic structure across seven focal populations and tested key demographic hypotheses associated with glaciation and aridification during the Pleistocene, such as the extinction and recolonization of painted turtles in the Great Plains region. Analyses of population structure indicate that, with the exception of Idaho and Oregon, populations are genetically distinct, contrary to prior results from a single mitochondrial locus study. These population genomic patterns may reflect limited dispersal, different population histories, and local adaptation to varied environmental conditions.

69-3 JUDY, C D*; BRUMFIELD, R T; GRAVES, G R; National Museum of Natural History, SI; Louisiana State University, Louisiana State University, National Museum of Natural History, SI; *caroline.duffie@gmail.com*

Morphological and Genetic Variation across a Narrow Hybrid Zone between Jamaican Endemic Streamertail Hummingbirds (Trochilus polytmus and T. scitulus)

We show that the sister species of streamertail hummingbirds (*Trochilus polytmus* and *T. scitulus*) diverged recently and *in situ* on Jamaica, with their divergence likely facilitated by sexual selection during a period of geographic isolation. The pair form a stable hybrid zone where their ranges meet in eastern Jamaica. Geographic cline analyses support the hypothesis that this hybrid zone is maintained as a tension zone, in which selection against hybridization is offset by the dispersal of parentals into the zone. Streamertail hummingbirds are highly volant, yet bill color, the secondary sexual ornament that distinguishes the taxa, changes from ruby red (*T. polytmus*) to jet black (*T. scitulus*) over less than 5 km. A genome scan based on AFLP markers, three independently segregating autosomal loci, the hypervariable mitochondrial control region, six microsatellite markers, and over 6,000 high quality SNPs from a genotyping-by-sequencing dataset show little if any genetic differentiation between the taxa that would support the presence of post-mating reproductive isolating mechanisms. Instead, our data suggest rapidly evolved differences in bill color acts as a strong pre-mating deterrent to hybridization.

P2-50 JUGAN, J*; DUNCKEL, K; CHAMBERS, DL; Saint Mary's College of California; *jaj4@stmarys-ca.edu*

Endo- and Ectoparasitism Associated with Elevated Androgens and Corticosteroids in Male Cost Range Fence Lizards (Sceloporus occidentalis bocourtii)

Knowledge of dynamics between an animal's ecology and physiology can empower conservation. Such efforts are essential as we are on the precipice of a biodiversity crisis, particularly among vertebrates. Vertebrates can have physiological trade-offs to their life histories. It is within these trade-offs that conservation context can be extracted. Some of the least understood vertebrate physiological trade-offs are associated with stress. Corticosteroids associated with stress typically inhibit non-essential processes, such as reproduction and immune system. Coast Range Fence Lizards (*Sceloporus occidentalis bocourtii*), specifically males, are intriguing models for physiological trade-off investigations. Males face tremendous pressure for successful reproductive events since they do not reach sexual maturity until late in life history. Most males only have one or two potential reproductive seasons. Thus, males often have simultaneously elevated androgen levels to help ensure reproductive success (e.g., territory defense, intraspecific competition, sperm production) and corticosteroid levels to mobilize energy for reproductive behaviors. However, the costs associated with simultaneously elevated androgens and corticosteroids are poorly understood. We hypothesized that male *S. o. bocourtii* would be more susceptible to parasitism as one potential physiological trade-off. We investigated the occurrence of ecto- (Western black-legged ticks, *Ixodes pacificus*) and endoparasites (*Plasmodium mexicanum*) in n=40 wild caught male *S. o. bocourtii*. Results could shed light onto potential physiological trade-offs to simultaneously elevated androgen and corticosteroid hormones, thus unraveling some complexities surrounding the current vertebrate biodiversity crisis.

53-3 JUNG, J*; MCDANIEL, JG; WARKENTIN, KM; Boston University; *jungj@bu.edu*

Ontogenetic Adaptation in Information Use for Escape-Hatching Decisions: Older Embryos Selectively Accept More False Alarms

Arboreal embryos of red-eyed treefrogs, *Agalychnis callidryas*, hatch prematurely to escape from egg predators, cued by vibrations in attacks. Young embryos modulate hatching based on multiple frequency and temporal properties of cues, reducing false alarms that unnecessarily expose them to risk in the water. Because the cost of false alarms decreases developmentally we hypothesize that, if sampling costs are high or stimuli ambiguous, older embryos accept more false alarms. We tested this using vibration playbacks at two developmental stages. In two experiments, we assessed changes in sensitivity to sampling costs. We designed sets of 3 stimuli, based on prior results with younger embryos, so one elicited high hatching and two elicited similarly low hatching, but sampling costs differed between low-hatching stimuli. Older embryos showed lower latency to hatch, indicating less cue sampling, and more hatching overall. Their similarly high responses to two of the stimuli suggest they ceased to discriminate using slow-to-assess properties as indicators of safety; however, they showed little hatching if either frequency spectrum or a fast temporal pattern allowed rapid assessment of low risk. In a third experiment, we controlled cycle length and information-delivery rate, but varied ambiguity, presenting temporal patterns that elicited high, medium, and low hatching of younger embryos. Older embryos again showed lower latency and more hatching, with the greatest change in response to the more ambiguous medium-hatching stimulus. Developmental changes in behavior due to ontogenetic adaptation of decision processes are likely to be widespread. Vibration-cued hatching allows us to use the power of playback experiments to improve our understanding of the development of adaptive embryo behavior.

P3-17 JUNG, J*; GÜELL, BA; WARKENTIN, KW; Boston University; *jungj@bu.edu*
Inner Ear Development Across Onset and Improvement of Escape-Hatching Ability in Red-Eyed Treefrogs: a Confocal and μCT Analysis
Arboreal embryos of red-eyed treefrogs, *Agalychnis callidryas*, hatch to escape from egg predators, cued by physical disturbance in attacks. A developmental match in the onset of otic function, measured by the vestibulo-ocular reflex (VOR), and mechanosensory-cued hatching (MCH) suggests that inner ear mechanoreceptors mediate this response. We present three new parts to this story. First, we manipulated development rate by rearing embryos under three thermal conditions (warm, ambient, cool) to assess consistency in the matched onset of VOR and hatching responses to simulated attack cues. Second, we employed confocal microscopy of whole otic capsules of embryos preserved just before and after the onset of MCH (about 3 h apart), visualizing F-actin and synapsin. Initial analyses suggest that VOR and MCH appear concurrently in each thermal treatment. Several morphometrics of inner ears, including abundance and density of stereociliary bundles and their synaptic connections, also appear to increase across hatching onset. Third, we collected a developmental series of high-contrast μCT images of embryo ears to visualize how gross morphology changes across the onset of MCH and through spontaneous hatching. Across the onset of MCH, structural complexity of ears increases, but growth is minimal. After MCH in response to strong cues becomes consistent, ears grow substantially through the rest of the plastic hatching period, while amplitude threshold for MCH in vibration playbacks decreases. Collectively, our morphological data suggest that ear development first enables then improves cue detection. Forming ears, even early in their development, may serve critical functional roles enabling embryos to detect and respond to predator cues.

3-5 JURCAK, AM*; MOORE, PA; Bowling Green State University ; *ajurcak@bgsu.edu*
Can you smell that predator? The effects of a common pesticide on the ability of two prey species to detect predatory stimuli
Many aquatic prey gain information from chemical signals in their environment to determine risk and avoid predation. However, the introduction of anthropogenic chemicals can disrupt the ability of an organism to detect olfactory cues in their environment. The purpose of this study was to investigate how the exposure of a pesticide (carbaryl) effected the ability of different prey (a native and invasive crayfish) to detect odor from a predator (largemouth bass). Crayfish were exposed to a sub-lethal concentration of carbaryl in a flow through model stream for 23 hours. Carbaryl was delivered to mimic a groundwater entry exposure. After exposure, crayfish were then placed in a two-current choice flume and exposed to a predator odor on one side of the flume and clean river water on the other side for a 12 minute behavioral trial. Behaviors quantified during the trial included time in each side of the flume, time in shelters, body posture, and activity levels. Results show that anthropogenic chemicals can alter the ability of crayfish to detect and respond appropriately to bass odor. This work highlights the importance of understanding the potential impacts that anthropogenic chemicals can have on the behavior of organisms and the ability to detect predatory threat.

P3-196 JURESTOVSKY, DJ*; MEAD, JI; East Tennessee State University, TN, Mammoth Site at Hot Springs, SD; *djj64@zips.uakron.edu*
Making Identifications Using Snake Cranial Bones
Snake skulls are typically analyzed as a whole but are rarely found complete in the fossil record, as snakes have highly kinetic skulls that separate quickly post-mortem. In this study, we compared the basioccipital, frontal, and compound bone of 24 species across four families and nine genera to discover whether individual cranial bones can be differentiated and to what taxonomic level. When comparing cranial bones individually, results showed dramatic differences at the family level for all three bone types. For the basiocciptial, lacking a crest or a weakly developed crest and wide anterior arc are characteristic of Pythonidae, a large sweeping crest and laterally narrow shape are characteristic of Viperidae, a weakly developed trilobate crest is typical of Colubridae, and a moderately-developed trilobate crest and lateral spines are typical of Natricidae. For the frontal, Pythonidae has a trapezoidal shape, Viperidae has a roughly square shape, Colubridae has a rectangular shape, and Natricidae has a well-developed medial process and a rectangular shape. For the compound bone, the arch of the shaft and multiple processes, among other characters, are informative. At the generic level, there appears to be potential for making identifications, however, certain genera are strikingly divergent from species to species, such as the Natricines. When comparing isolated cranial bones at the species-level, preliminary results suggest there is too much variance and/or similarity to obtain an accurate identification. Snake cranial bones display a wide array of forms and it appears promising that, like snake vertebrae, generic-level identifications are possible, but more research is needed to determine intraspecific variation and expand upon the cranial bones selected here.

95-5 KAHN, AS*; MATVEEV, E; LAW, LK; YAHEL, G; LEYS, SP; Univ. of Alberta, Ruppin Academic Center; *kahn@ualberta.ca*
The Role of Biodiversity in Benthic-Pelagic Coupling by Glass Sponge Reefs
Suspension feeders transfer carbon and nutrients from the water column into benthic communities. Sponges in particular link the biomass of the pelagic microbial loop to animal food webs by filter feeding on bacteria. On ship cruises between 2004 and 2017, glass sponge reefs in British Columbia, Canada were surveyed to measure live sponge cover, species composition, sponge density, volumetric pumping rate, and bacterial carbon consumption. Combined, these numbers were used to estimate the benthic grazing rate of a square meter patch of reef, then scale up to the entire expanse of reefs. Glass sponge reefs in the Strait of Georgia, composed predominantly of *Aphrocallistes vastus*, are estimated to process 130-290 m^3 m^{-2} d^{-1} of water and to import up to 1.5 kg of bacterial biomass per square meter of reef annually. Sponge reefs in Hecate Strait are dominated by different species, either *Farrea occa* or *Heterochone calyx*. We set out to determine whether the strength and nature of benthic-pelagic coupling by reef sponges is affected by species diversity. We found that at least two reef subtypes exist in Hecate Strait: those dominated by *F. occa* and those dominated by *H. calyx*, and that both have different levels of water processing capacity and bacterial uptake in comparison with the *Aphrocallistes*-dominated reefs in the Strait of Georgia. The degree of benthic-pelagic coupling, and likely other ecosystem services, therefore varies depending on reef community structure. Understanding this variability is an important consideration for future conservation planning to protect sponge reef habitats.

58-2 KAHRL, AF; Stockholm University; *ariel.kahrl@gmail.com*
Understanding the evolution of extreme variation in sperm morphology between snakes and lizards
During postcopulatory selection, sperm competition may select for a variety of ejaculate traits, including sperm morphology, count, and sperm function. Because ejaculate production is energetically expensive, tradeoffs (e.g. sperm size vs. sperm number) may generate correlated evolution of these traits. By examining testis size and sperm morphology together in a phylogenetic framework, we can better understand the processes that generate the extreme variation in sperm morphology we see among species. We collected data from the field and the literature on sperm morphology (sperm head, midpiece and tail length), testis size, and body size for 81 species of snakes and lizards. Using phylogenetic least squares regressions, we found a strong positive correlation between testis size and midpiece length, and a marginal negative correlation between body size-corrected testis size and tail length. When we examined snakes and lizards separately, we found differing patterns between the groups, such that snakes exhibited a strong positive correlation between midpiece length and testis size, whereas there were no correlations between sperm morphology and testis size in lizards. To understand how these traits evolve as a suite of traits, we tested for differences in the Brownian rates of evolution of testis size, body size, and sperm morphology in snakes and lizards separately. We found that, relative to other traits, body size-corrected testis size and midpiece size evolve faster in snakes than in lizards. This suggests that the midpiece may be more may be under stronger selection in snakes than in lizards, potentially due to differences in the mating systems and reproductive physiology between the groups.

101-2 KAJIURA, SM*; WALDRON, JM; Florida Atlantic University; *kajiura@fau.edu*
Seasonal Abundance and Spatial Distribution of Blacktip Sharks (Carcharhinus limbatus) in Southeast Florida
Southeast Florida experiences an enormous seasonal influx of upper trophic level marine predators each year as blacktip sharks (*Carcharhinus limbatus*) migrate south to overwinter in nearshore waters. These sharks form aggregations ranging from a few individuals to thousands. The sharks are often found in very shallow water, only a few meters from popular swimming beaches which raises concerns about potential negative interactions. To quantify shark abundance and distribution, an aerial survey was conducted during peak season (December - April) from 2011-2017. A low altitude (150m) survey flight was flown from Government Cut (South Beach, Miami) to Jupiter Inlet at approximately biweekly (2011-2014) or weekly (2015-2017) intervals. A high definition video camera recorded a transect from the beach to approximately 200m offshore. Segments of the survey transect were demarcated by inlets, and the number of sharks found within each segment was counted to calculate shark density. During the seven year study, the greatest shark density was consistently found in February and March. Although sharks were seen throughout the entire 132km length of the survey transect, significantly greater numbers of sharks were found at the northernmost third of the transect in Palm Beach County (Boynton Beach Inlet to Jupiter Inlet) where densities exceeded 1,000 sharks km^{-2}. The habitat throughout the transect is largely consistent, so it remains unclear why the sharks are not distributed farther south. Southward migrating sharks might simply stop once they reach appropriate conditions and warming oceans might eventually restrict their migration to increasingly higher latitudes.

72-5 KALYANASUNDARAM, P*; WILLIS, M; Case western Reserve University, Cleveland ; *tk.parthasarathy@gmail.com*
Odor arrival side discrimination in Manduca sexta
The hawkmoth *Manduca sexta* uses odors to find mates, food and egg-laying sites. Odor molecules are distributed by moving air into a non-uniform, patchy cloud known as a plume. While tracking an odor plume, *M. sexta* drive their antennae through the odor plume along a zigzagging flight track in a relatively narrow range of flight speeds. Their flapping wings also draws air and odor through their antennae. These behaviors could work together to sample the odor environment both in space and time and this information may be used to alter steering maneuvers to maintain contact with the plume. One element of this spatial odor information could come from bilateral comparisons between the two antennae. The prerequisite for this strategy to work is that the moth must be able to discriminate which antenna is being stimulated. To address this question, we designed an odor arrival side discrimination task based on the proboscis extension reflex conditioning. Proboscis extension was monitored by recording electric potentials generated by the cibarial pump muscle that is involved in drawing nectar up the moths' proboscis. Initially, the moths were presented 10-12 trials of conditioning stimuli i.e., odor stimulation to one of the antennae was associated with sucrose reward. Following this, moths were tested for cibarial muscle activity when odor was presented from either the associated or unassociated side. The moths were expected to generate cibarial muscle potentials when presented with odor on the associated side and remain relatively quiet during odor presentation to the other side. Moths discriminated the odor arrival side with an accuracy of >70%. These results show that moths may be able to determine the odor plume location in 3D space, and use this information to control the turning maneuvers used during plume tracking.

114-6 KAMRAN, M*; DITTMAN, A.H; POLLOCK, A.M; NOAKES, D.L.G; Oregon State University, Northwest Fisheries Science Center, National Marine Fisheries Service, NOAA, Oregon State University, Oregon Hatchery Research Center ; *maryam.kamran@oregonstate.edu*
Smells like home: Using olfactory learning and conditioning assays to select odorants for olfactory imprinting and homing in Pacific salmon
Within an aquatic environment, olfactory cues are essential for successfully mediating behaviors such as foraging, recognition of conspecifics and avoidance of predators. Furthermore, olfactory cues play an important role in habitat recognition and subsequent site fidelity across a number of species. The spawning migrations of anadromous salmonid fishes are remarkable navigational feats that occur over both significant spatial and temporal scales, with adults returning to their natal streams after several years. Olfactory cues are critical for successful homing. In addition, olfactory imprinting of odors at specific developmental stages appears to be the mechanism through which juvenile fish learn site-specific odors of their home streams. While salmonids can readily detect different classes of compounds at relatively low levels within freshwater ecosystems, natural odorants that may serve as temporally persistent and stable migratory cues remain unidentified. Here we select odorants that not only improve olfactory imprinting but are also cost effective compounds that can be incorporated for hatchery management. By improving olfactory imprinting and thereby reducing straying of hatchery fish, we can reduce negative interactions between hatchery and wild salmonid populations. We test the efficacy of various odorants as potential navigational cues by conducting a series of behavioral assays including testing for innate behavioral responses to select compounds and determining olfactory learning abilities through odor conditioning.

P2-41 KANARSH, P/I*; ROSERO, M/A; ZAVALETA, J/A; FUSE, M; San Francisco State University; *pkanarsh@mail.sfsu.edu*

Developing a method of imaginal disc transplants in the hornworm, Manduca sexta

Holometabolous insects undergo radical body changes from larvae through adulthood, which has allowed them to increase their range of geographic niches. Many of the adult structures arise from highly proliferating stem cell-like primordial tissues, called imaginal discs. When damaged, they affect extended larval and pupal development. This is assumed to provide time for regeneration. However, it has not yet been verified the delays are a result of imaginal disc damage or undocumented damage to other tissues. We hypothesized the damage to disc tissue was the main factor contributing to developmental delays and developed a transplant method to compare the effects of transplanting irradiated (damaged) discs into healthy larvae with the goal of delaying development. We transplanted irradiated and non-irradiated discs into healthy larvae with and without removing their original discs and monitored developmental timing. Removing the original discs appeared to be very traumatic, masking the effects of damage incurred via irradiation. That is, larvae receiving transplants - regardless of damage status - showed delays to pupation that were close to delays in irradiated controls. The delays were longest to the adult stage in transplanted animals - even longer than irradiated controls. These data indicate that the mechanical action of removing a recipient's discs and inserting discs from a donor, whether or not the donor was irradiated, caused developmental delays. Preliminary results on effects of transplants into recipient animals that still have their original discs suggests that irradiated disc insertion delays development more than the insertion of non-irradiated discs. If these results are confirmed, then we have a useful method for assessing the role of damaged discs in regulating development, and can begin to assess the effects of different levels of radiation damage on development.

P1-25 KANASIRO, A*; DAZA, JD; BELL, CJ; MAISANO, JA; GAMBLE, T; BAUER, AM; Sam Houston State University, University of Texas at Austin, University of Texas at Austin, Marquette University, Villanova University; *kanasiro.andre@gmail.com*

Learning to Fly: Skeletal Evolution in Gliding Geckos

Gliding behavior evolved independently at least three times in geckos, presumably in a coevolution of complex phenotypic characters associated with crypsis, gliding, and a behavioral trait known as ‘voluntary leap'; the Indopacific gecko group (IGG) includes forms that developed novel peramorphic traits, suggesting an evolutionary trend towards skull reinforcement. These complex skull traits (namely synostosis, development of crests, and hypermorphosis of skull bones) have been interpreted as adaptation to feeding biomechanics; however, they might also indicate some reinforcement of the skull to provide additional protection to the brain and special sense organs from landing impacts after gliding or jumping. To test this idea, skulls from several IGG taxa were analyzed using HRCT data and X-rays. Changes in the axial axial skeleton include presence of a supraoccipital dorsal process and a prefrontal canthal crest in the gliding genus *Ptychozoon* and closely related forms from *Luperosaurus*. Changes are not limited to the skull, for gliders also exhibit expanded wrists and ankles, as well as a reduction in the height of vertebral arches and modifications of ribcage morphology. Some of these traits are also found in non-gliding taxa (e.g. *Gekko*), which suggests that these traits are exaptations that coevolved with behavioral traits, such as ‘voluntary leap' performance, prior to the origin of gliding.

P3-31 KANE, S.A.*; VAN BEVEREN, D.; DAKIN, R.; Haverford College, Smithsonian Conservation Biology Institute; *samador@haverford.edu*

Biomechanics of the peafowl's crest: a potential mechanosensory role for feathers during social displays

Feathers act as sensors to detect mechanical stimuli during avian flight and tactile navigation, suggesting that they may also function to detect signals during social displays. In this study, we used laboratory experiments to determine whether the airborne stimuli generated by Indian peafowl (*Pavo cristatus*) courtship and social displays couple efficiently via resonance to the vibrational response of feather crests from the heads of peafowl. Peafowl crests were found to have fundamental resonant modes with frequencies that could be driven near-optimally by the shaking frequencies used by peafowl performing train vibrating displays. Crests also were driven to vibrate near resonance when audio recordings of sounds generated by these displays were played back in the near-field, where such displays are experienced in vivo. When peacock wing-shaking courtship behaviour was simulated in the laboratory, the resulting directional airflow excited measurable vibrations of crest feathers. These results suggest that peafowl crests have properties that make them suitable mechanosensors for multiple potential airborne signals generated during social displays. Diverse feather crests are found in many bird species that perform similar displays, suggesting that such sensory functions may be widespread and derived from flow sensing in other contexts. We suggest behavioral studies to further explore these ideas and their functional implications.

30-4 KANE, EA*; GHALAMBOR, CK; Georgia Southern University, Colorado State University; *ekane@georgiasouthern.edu*

An ecological specialization gradient does not lead to performance specialization in suction-feeding guppies

The way an organism interacts with its environment is the result of multiple systems working together, often in the face of one or more tradeoffs. Therefore, as organisms adapt along environmental gradients, the balance between these system also likely shifts. For example, Trinidadian guppies (*Poecilia reticulata*) have repeatedly evolved correlated changes in morphology, diet, and behavior along an environmental gradient of predation risk and competition for prey, suggesting a shift in the balance from predator escape to feeding performance, respectively. Much work has demonstrated differences in locomotor morphology, performance, and survival in guppies along this gradient, but demonstration of reciprocal changes in feeding performance have been few. One study suggested that higher feeding rates in the absence of predation were the result of morphological changes in the jaws, indicative of potentially faster movements and stronger suction during prey capture. We tested this hypothesis directly by examining the suction-feeding mechanics of replicate high and low predation pairs of guppies capturing suspended live plankton prey. Our work presents three lines of evidence refuting this hypothesis: there were no differences between populations in induced prey velocity due to suction, suction-feeding kinematics, or capture success rates. Therefore, a tradeoff in suction-feeding is not apparent across a shift in selection gradients in guppies. We propose either that guppies represent a generalist feeding phenotype that does not specialize to habitat, or that performance differences may instead be apparent when guppies capture prey using biting, as this is a more morphologically specialized type of prey capture for these fish.

99-2 KANE, S.A.*; DAKIN, R.; LU, Y.; FANG, R.; Haverford College, Smithsonian Conservation Biology Institute; *samador@haverford.edu*

Courtship display dynamics and iridescent structural color in peacocks and related ocellated pheasant species

Peacocks court females by tilting a fan-like array of feathers decorated with multicolored eyespots (ocelli). Previous research has shown that half of the variation in peacock mating success can be attributed to eyespot iridescence. Several closely-related pheasant species also perform similar, but less complex, courtship displays using ocellated feathers with less complex coloration, patterns and underlying nanostructures. This study explores the relationship between the dynamics of male courtship behavior and optical properties of each species' iridescent feather ornaments. In particular, we examined videos of courting males and of individual feathers to measure how the angles used during displays compared to those corresponding to optimal eyespot reflected intensity and iridescent contrast. Bidirectional reflectance spectroscopy was used to measure how the spectrum of reflected light depends on the characteristic angles used during displays, and hence how displays stimulate the four classes of cones found in the color vision systems of these birds. This work reveals the relationship between courtship display kinematics and the angular dependence of iridescent feather reflectance properties.

P2-68 KARJASEVIC, A*; MILANO, L; NAGLE, FS; MCCUE, MD; HATLE, JD; Univ. of North Florida, St. Mary's Univ. Texas; *jhatle@unf.edu*

Dietary restriction increases oxidation of some branched-chain amino acids in grasshoppers

Dietary branched-chain amino acids (BCAAs) are commonly taken for muscle development. However, by stimulating growth via the Target of Rapamycin pathway, they may be detrimental to lifespan. We recently hypothesized that life-extension upon dietary restriction (DR) may result in part from increased oxidation of BCAAs, hence making them unavailable to overstimulate growth. Lubber grasshoppers (*Romalea microptera*) were chronically fed two levels of lettuce and BCAAs: ad libitum & BCAAs, ad libitum & buffer, DR & BCAAs, and DR & buffer. The BCAA solution contained the BCAA in the proportions found in lettuce. Lettuce dietary restriction decreased oviposition, but no difference in oviposition was seen upon BCAA force feeding. Dietary treatments were applied daily for at least 50 days (~1/3 of the lifespan) before sampling for hemolymph levels and oxidation rates, both in individuals. Hemolymph samples were collected >12h after any force feeding or lettuce feeding. In general, upon lettuce dietary restriction, BCAA force feeding slightly increased hemolymph BCAAs while buffer force feeding slightly decreased hemolymph BCAAs. The effect was significant for isoleucine ($P_{interaction}$=0.042) and a trend for valine and leucine (P=0.105). There was no effect on hemolymph levels of BCAAs within the ad libitum-fed groups. Lettuce dietary restriction doubled the peak rate of oxidation of BCAAs (P<0.0001). In particular, peak oxidation rates were tripled for isoleucine (P<0.02), doubled for valine (P<0.04), and increased 50% for leucine (NS). Force feeding of BCAAs had little effect on oxidation of any BCAA. Based on these results, dietary restriction has two routes to reducing the availability of BCAAs (esp. isoleucine), which may reduce its availability to stimulate growth.

25-4 KARSTEN, KB*; CUADRADO, M; California Lutheran University, Zoobotanico Jerez; *karsten@callutheran.edu*

Sexual Selection on Performance in a Size-monomorphic Mating System, Chamaeleo chamaeleon from Southern Spain

Male-biased size dimorphic mating systems are often characterized by strong male-male aggression and competition for mates. Thus, these mating systems are often classic study systems to test hypotheses of sexual selection. In contrast, it may be harder to delineate the role of sexual selection in size monomorphic mating systems as there are a multitude of selection processes that may be occurring concomitantly. Although body size is often one important variable in determining male mating success in many species, selection may favor other secondary morphological traits that manifest functionally into whole-animal performance, which could directly influence fitness. Thus, sexual selection on performance may allow for a way to detect if there is sexual selection for dimorphism even if no observable SSD exists. Here, we study a size-monomorphic mating system, the common chameleon from southern Spain. Because male chameleons fight each other by biting opponents, we tested the hypotheses that 1) males are dimorphic from females in this important performance ability and 2) because bite performance is often correlated with head morphology, that this trait would also be sexually dimorphic. We found that, when controlling for body size, male chameleons significantly differed in head morphology than females, most notably in the cranial casque (which is strongly correlated with bite force performance). In addition, males were sexually dimorphic in bite force, with significantly stronger bite forces than females for a given body size. We conclude that there is sexual selection on performance in this species despite the lack of selection that would generate differences in body size between the sexes.

129-2 KASOJU, VT*; FORD, MP; SANTHANAKRISHNAN, A; Oklahoma State University; *askrish@okstate.edu*

Leaky Flow Through Bristled Wings of Tiny Insects

Tiny insects with body lengths under 1 mm, such as thrips and fairyflies, use bristled wings for flapping flight at Reynolds number (Re) on the order of 10. Thrips have also been observed to use wing-wing interaction via the clap and fling mechanism. We examine how varying the gap or spacing between a pair of bristles (G) relative to bristle diameter (D) impacts the forces and flow structures generated during wing-wing interaction. The bristle gap to diameter (G/D) ratios in a number of thrips species were quantified from published data. Physical models of bristled wing pairs with G/D in the range of 5-17 and a geometrically equivalent solid wing pair were developed for this study. These physical models were tested using a dynamically scaled robot that was programmed to execute clap and fling kinematics. Non-dimensional lift and drag coefficients were estimated from strain gauge measurements of time-varying forces. Phase-locked particle image velocimetry (PIV) measurements were used to examine flow through the bristles. Chordwise PIV measurements were used to visualize leading and trailing edge vortices formed over the wings during flapping. The results show that both lift and drag forces reduce with increase in G/D. However, spanwise flow around the bristles reduce the drag force by a larger proportion relative to the reduction in lift force, thus increasing the lift to drag ratio.

10-5 KATHMAN, ND*; FOX, JL; Case Western Reserve University; *ndk9@case.edu*

Mechanosensory and visual integration in the fly central complex

The reduced hindwings of flies, known as halteres, are specialized mechanosensory organs that detect inertial forces associated with body rotation during flight. Previous studies have shown that primary afferents of the haltere encode its oscillation frequency linearly over a wide bandwidth and with precise phase dependent spiking. It is not currently known whether information from haltere primary afferent neurons is sent to higher brain centers, or whether precise spike timing is useful beyond the peripheral circuits that drive wing movements. We show that in cells in the central brain, the timing and rates of neural spiking can be modulated by sensory input from the haltere. Using multichannel extracellular recording in a restrained flesh fly (Sarcophaga), we examined responses of central complex (CX) cells to a range of externally imposed haltere oscillation frequencies and visual motion speeds. Haltere-responsive units fell into multiple response classes, including those with firing rates linearly related to the haltere frequency and others with responses independent of frequency. We also investigated the responses of CX units when the fly was stimulated with both haltere oscillations and visual motion. Units that responded to both stimulus types when presented independently showed higher firing rates when both stimuli were presented simultaneously. Multimodal responses in these cells either varied with haltere frequency, independent of visual speed, or were sensitive to a narrow range of stimulus parameter combinations. Although haltere inputs have largely been studied in the context of rapid locomotion control, we have found haltere sensory information in a brain region known to be involved in slower, higher-order behaviors, such as navigation. This data, along with recordings from tethered walking animals, may indicate a role in behaviors that take place over a longer timescale.

138-4 KATIJA, K*; SHERMAN, A; SHERLOCK, R; ROBISON, B; Monterey Bay Aquarium Research Institute, Moss Landing; *kakani@mbari.org*

DeepPIV Reveals How Mucus Houses of Deep Sea, Giant Larvaceans are Built

Larvaceans (Class Appendicularia) are found throughout the world's oceans and affect food webs across trophic levels via elaborate mucus feeding structures they create. Larvaceans swim tethered to their mucus houses, forcing seawater and particles through filters that eventually lead to their mouth. In Monterey Bay, giant larvaceans (Genus *Bathochordaeus*) can be found between 50 and 400 m, and can build mucus houses as large as 1 m across. While pumping fluid through their mucus houses, giant larvaceans are able to filter as much as 80 L/hr, consume and repackage microplastics, and contribute significantly to carbon cycling in the oceans due to their abandoned, sinking houses. Despite having such an important ecological role, little is known about the structure and function of giant larvacean houses. Using DeepPIV, an instrument that is mounted to a remotely operated vehicle (ROV) that is deployable from the sea surface to 4000 m, we can conduct quantitative in situ measurements of (1) fluid motion and (2) 3D reconstructions of mucus and gelatinous structures. During a deployment of DeepPIV in 2015, we observed a giant larvacean, Bathochordaeus stygius, building its house. In the 25+ year history of ROV observations in Monterey Bay, this behavior has only been partially observed one other time. With DeepPIV, we were able to observe changes in the mucus house over time, which reveals surprising arrangement of structures that have important implications to giant larvacean ecology.

P1-14 KATZ, HR*; GOOLSBEE, A; HALE, ME; Univ. of Chicago; *katz20h@uchicago.edu*

Performance of axial and limb-based startle behaviors through metamorphosis in Xenopus laevis

The startle response is vital to an organism's survival. Animals must perform startle throughout life history as they undergo changes in their body shape and nervous system. Anurans (frogs and toads) undergo metamorphosis, during which time the limbs develop, the tail is lost, and the trunk stiffens. At intermediate metamorphic stages, they are particularly susceptible to predation. Here we ask how a critical function, startle, is maintained through a switch in its underlying morphology in the African clawed frog (*Xenopus laevis*). Tadpoles have been shown to perform an axial-based C-start, much like the response observed in fish. We found that *X. laevis* gradually integrate a limb-based "pushback" response into their startle repertoire starting at developmental stage 58. We hypothesized that there is a critical period during metamorphosis when the C-start performance declines and the pushback has yet to reach peak performance levels. We performed high-speed video recordings of startle trials of 18 animals ranging from stage 57, when only C-starts are performed, to 66, when metamorphosis is complete and startles are limb-based. For pushback, we found that maximum and average velocity (bl/s) increased significantly with metamorphic stage. From these and other parameters, we conclude that pushback performance improves through metamorphosis from stage 58 to stage 66. We could elicit C-start responses up through stage 63, but curvature of the trunk becomes limited from stage 61-63, resulting in a negative impact on performance. These data indicate that there is a period where neither startle strategy is functioning at peak performance, and the animal may be more vulnerable to predation.

58-1 KAWAGUCHI, M*; HARADA, A; YASUMASU, S; Sophia Univ., Japan; *k-mari@sophia.ac.jp*

Formation of seahorse brood pouch

Seahorses are unique in mode of reproduction, i.e., male, not female, carries embryos in a brood pouch located on the ventral surface of the tail. In order to study how the brood pouch is formed during the development of male seahorses from juvenile to adult, we made histological observations of various stages of brood pouch development. First, brood pouch of mature male was observed by hematoxylin-eosin stain, Masson trichrome stain, and reticulin silver stain. As results, the brood pouch was composed of internal epithelium called "pseudoplacenta", dermis layer and surface epithelium from inside to outside. The dermis layer contained dense connective tissues indicated by blue color with Masson trichrome stain. The "pseudoplacenta" contained loose connective tissues indicated by black color with reticulin silver stain. These results suggest that the dermis layer is mainly composed of collagen fibers, while the "pseudoplacenta" is mainly composed of reticular fibers. A lot of mucus cells were observed in the surface epithelium, while few were in the internal epithelium. Next, brood pouch formation process was observed. In juvenile male seahorse, the dermis of both sides of body seemed to rise and elongate toward the midline of the body. At the beginning, the pouch was only composed of dermis. As development proceeded, smooth muscle in dermis layer and "pseudoplacenta" were differentiated. The "pseudoplacenta" appeared to be formed from the dorsal parts of the pouch, and finally surrounded the pouch. At the beginning, there were no remarkable morphological differences between internal epithelium and surface epithelium, and the mucus cells were observed in the both epithelia. As development proceeds, the number of mucus cells decreased in the internal epithelium, and finally few mucus cells appeared to be observed in mature seahorses.

P1-281 KAY, D/I*; ERICKSON, G/M; Oklahoma State University, Center for Health Sciences, Florida State Univeristy; *david.kay@okstate.edu*

Material Property Evolution of Mineralized Dental Tissues in Gnathostomes

During gnathostome diversification modifications to dental form and mineralized tissues (enamel, dentines, and cementum) facilitated the exploitation of novel food resources. Generally, it has been assumed that the intra-tissue biomechanics of these constituents had little bearing on whole-tooth functionality, aside from mammalian enamel in occluding dentitions. Many mammals, for example, possess teeth that self-wear to functionality with a diversity of derived tissues—some which possess unique mechanical attributes to resist wear and fracture. Here we formally test the hypothesis that g nathostome dental tissue material properties were static prior to the cladogenesis of Mammalia. Hardness and elastic modulus were tested using two standardized material science techniques, microindentation and nanoindentation, as well as a novel approach for quantifying fracture propagation from indentation cracks. These data were analyzed in a modern phylogenetic and ecological context. The results show these material properties to be highly variable within and between groups. Aside from enamel hardness, there is no significant relationship between most material properties and diet. An ancillary goal of this work is also to glean initial insights about how dental attributes for non-mammalian and mammalian taxa more generally may contribute to whole-tooth form, function, performance, and diet. Complex fracture patterns in the enamels of mammals and chondrichthyans, for example, show that gnathostome lineages independently evolved traits to control fracture and minimize damage. Overall, this study suggests that selection operated at the tissue level to bring about shifts in whole-tooth functionality across Gnathostomata.

103-5 KEER, S*; HERNANDEZ, LP; The George Washington University; *skeer@gwu.edu*

Earliest development of the palatal organ in zebrafish

Cypriniforms dominate the Earth's fresh water systems and possess several evolutionary novelties, many of which are associated with feeding. One such novelty is the palatal organ, a fleshy pad attached to the roof of the buccal cavity. In goldfish and carp, where this structure has been most thoroughly studied, the palatal organ is used to sort food from sediment during bottom feeding. In other species, the structure is greatly reduced and its function is unclear although it has been found in all Cypriniforms examined thus far. There has been little ontogenetic work done on the palatal organ in any species. Moreover, given that it has been suggested that the palatal organ does not exist in zebrafish, little effort has gone into documenting its early development in this popular model species. Here we use the Cypriniform and model organism *Danio rerio* to investigate the muscle and nerve development of this novel feeding structure. The palatal organ begins development at 60 hours post-fertilization (hpf) as fast skeletal muscle fibers appearing near the posterior of the buccal cavity. From 60 hpf to 84 hpf, muscle fibers move up toward the anterior of the buccal cavity and begin to thicken. During this period of anterior movement, the disorganized muscle fibers anchor themselves to the gill musculature from posterior to anterior. By 6 days post-fertilization the palatal organ is heavily innervated and is in an anatomical position similar to that seen in the adult. These results indicate much earlier muscle development and innervation than was originally thought. Understanding the earliest development of the palatal organ, specifically where this structure first arises in development, can inform us about how this feeding novelty may have arisen during the course of evolution.

P2-38 KEER, S*; MAY, CM; MCMENAMIN, S; HERNANDEZ, LP; The George Washington University, Boston College; *skeer@gwu.edu*

The role of thyroid hormone in skeletogenesis of zebrafish

Thyroid hormone is critical for the normal development and regulation of a variety of cellular and organismal processes, particularly those involving the skeletal system. Mouse and rat models have been traditionally used to study thyroid hormone, but the fast generation time and ease of genomic manipulation of zebrafish makes them an excellent tool to investigate the effects of thyroid hormone disruption. Therefore, a thorough anatomical assessment of the differences in the adult hypo-, eu-, and hyperthyroid zebrafish is important for those who wish to use zebrafish as a model organism for thyroid research. We studied the effects of thyroid disruption on skeletal development using both transgenic hypothyroid and mutant hyperthyroid lineages of *Danio rerio*. Anatomical analyses revealed that in hypothyroid zebrafish, there are significant anomalies in development of the dermatocranium. Specifically, parietal and frontal bones failed to properly fuse. Moreover, the radials of the pectoral fin also underwent improper development. In addition, hyperthyroid zebrafish exhibit greatly enlarged neural spines, haemal spines, and dentaries. Our results suggest that thyroid hormone plays a key role in skeletogenesis within the entire body of the zebrafish. By thoroughly investigating and comparing the anatomy of hypo-, eu-, and hyperthyroid zebrafish, we are better able to understand the role of thyroid hormone in skeletal development in vertebrates in general.

14-1 KELLY, TR*; MACDOUGALL-SHACKLETON, SA; MACDOUGALL-SHACKLETON, EA; Western University, Ontario, Canada; *tkelly43@uwo.ca*

Effects of experimental Plasmodium infection on spring migratory behavior and body condition in white-throated sparrows (Zonotrichia albicollis)

Seasonal migration exposes animals to a variety of habitats and parasites, thus energetic constraints may prevent simultaneously investing in immunity and migration. If infected migratory birds migrate successfully, there is great potential for birds to transport infectious diseases long distances. To determine whether parasitic infection alters or interferes with songbird migration, we inoculated captive white-throated sparrows (*Zonotrichia albicollis*) with malaria parasites (*Plasmodium* spp.) in late winter, corresponding to the initiation of spring migration. We assessed infection success and parasite loads, nocturnal migratory restlessness (*zugunruhe*), and body composition (fat mass, lean mass, and hematocrit). Experimentally-infected birds did not differ from controls in their in fat and lean mass, however, infected birds had lower hematocrit than controls following peak infection. All birds exhibited migratory restlessness, however, at the onset of infection infected individuals displayed less *zugunruhe*. This may reflect a delayed migratory departure in wild birds. Thus, although infected birds appear to exhibit normal *zugunruhe*, there may be subtle effects on migration onset and capacity for sustained flight. Models of disease spread depend on knowing whether or not infection affects migratory behaviour, making this research crucial to understanding future host/pathogen dynamics in our changing climate.

14-7 KELLY, TR; BONNER, SJ; MACDOUGALL-SHACKLETON, SA; MACDOUGALL-SHACKLETON, EA*; Western University; *emacdoug@uwo.ca*

Exposing migratory songbirds to malarial parasites suggests costs of resistance, not of infection

Migratory birds move through multiple habitats and encounter a diverse suite of parasites. This raises concern over migrants' potential role in transporting infectious disease between the breeding and wintering grounds, and along migratory flyways. Trade-offs between migratory flight and immunity may result in parasitized individuals delaying migration, with important effects on infection dynamics. However, experimental evidence that parasitic infection affects migratory timing remains scant. We hypothesized that encountering haematozoan parasites alters migratory timing and body condition, due to the infection itself and/or to the costs of mounting an immune response. To test this hypothesis, we experimentally inoculated song sparrows (*Melospiza melodia*) with an endemic strain of *Plasmodium* shortly before fall migration. We monitored infection success and body composition, and used radiotelemetry and mark-recapture analysis to infer migratory departure after release. Individuals that resisted acute infection despite exposure to parasites had lower lean mass twelve days after exposure than individuals that became acutely infected or controls inoculated with uninfected blood. This suggests trade-offs between body composition and immunity, either because resistance is energetically costly and/or because heavier individuals are more susceptible to infection. By contrast, we observed no significant difference between the resistant, acutely-infected, and control groups in timing of migratory departure. Experimentally evaluating the effects of infection and resistance on migratory timing and preparation in free-living animals is increasingly crucial, as parasite and vector ranges shift in response to a changing climate.

P2-194 KELSAY, TS*; DEBAN, SM; University of South Florida; *tkelsay@mail.usf.edu*

Temperature sensitivity of swimming in salamanders

Temperature is a fundamental variable that affects performance of many biological systems. Muscle-powered movement is especially thermally sensitive in ectothermic tetrapods, therefore, swimming performance of salamanders is expected to be significantly affected by temperature changes. However, previous studies have shown that some salamanders show surprisingly low thermal dependence of swimming velocity. To investigate the generality of these findings, we imaged swimming in *Ambystoma maculatum*, *Desmognathus ocoee*, *Desmognathus quadramaculatus*, and *Eurycea wilderae*. Swimming performance was tested in a temperature-controlled bath at 7 and 17°C. Swimming velocity decreased as temperature decreased, but thermal sensitivity of swimming velocity was lower than that of limbed locomotion in ectothermic tetrapods that have been examined, confirming earlier studies. Investigating the energetics, fluid flow and motor control of swimming would yield insight into the curiously low temperature sensitivity of swimming in salamanders.

36-7 KENNEDY, J.*; NAGPAL, R.; Harvard University; *jokennedy@g.harvard.edu*

3) Using Drones to Visualize Formation of Damming Complexes of the North American Beaver (Castor canadensis)

Beavers display a uniquely broad range of constructive behaviors. In addition to the build of their dams, beaver further alter their environment through the excavation of canals and pond bottoms, construction of lodges and burrows, and felling of timber. This range of constructive behavior forms a network of critical locations to resources over several miles of riparian ecosystems. As a result of such activities, beavers can create extensive and complex aquatic and terrestrial networks that can only be readily observed from a bird's eye vantage. A single colony of beaver can be responsible for the construction of up to 18 dams in a single network. In order to observe network development and damming complexes, Parrot Bebop drones and a DJI Phantom Drone were used to monitor the active building season of the North American Beaver (*L. Castor canadensis*) in northwestern Montana. Drone imagery, coupled with AgiSoft Photoscan offers a reliable means to render 3D constructions of beaver damming networks. Drone imagery provides a reliable method to observe, in high resolution, changes and growth in a beaver damming complex over an active building season. These results offer one of the first insights into the scope of beaver building activities.

P3-203 KEOGH, J*; BAKER, JA; KING, RW; FOSTER, SA; Clark University ; *jakeogh@clarku.edu*

Temporal Patterns of Armor Evolution in Threespine Stickleback Fish Following Establishment of a Non-Native Predator, the Northern Pike

Invasive predators can have devastating ecological and evolutionary impacts on native prey species within the ecosystems they invade. These effects may be pronounced when the predator is novel to the prey, a situation that is on-going in southcentral Alaska, where the large and voracious northern pike are invading the native range of the threespine stickleback. In this area, pike have caused the extirpation of several populations of stickleback, yet in some instances stickleback have persisted. Here, we report on phenotypic changes following introduction of pike into Scout Lake, Alaska, in which the stickleback persisted. In 2001 or 2002, pike were illegally introduced to Scout Lake. A fortuitous set of annual collections of stickleback from Scout Lake, beginning prior to the introduction of pike and continuing until the lake was poisoned by the Alaska Department of Fish and Game in 2009 to eliminate pike, makes it possible to evaluate the speed and temporal pattern of armor modification and shape change in stickleback. Preliminary data suggest that over this very short timeframe, stickleback evolved more robust armor (spines, lateral plates, and elements of the pelvic girdle), and possibly reduced body depth. The armor effects are directly related to predator deterrence, but the possible body shape changes suggest that stickleback were shifting from foraging on benthic habitats along the shoreline where pike hunt, to foraging on plankton in open water. A more fusiform body would be advantageous in such a situation. Here we evaluate changes in body shape and armor robustness over the pre-pike and post-pike periods to evaluate the extent, speed, and temporal pattern of contemporary evolution and the degree to which the two classes of traits evolve in concert.

S10-11 KERNBACH, ME*; MILLER, JM; UNNASCH, TR; MARTIN, LB; University of South Florida; *kernbach@mail.usf.edu*
Light Pollution Increases Host Competence to West Nile Virus in a Reservoir Species
Humans can negatively impact wildlife behavior and physiology by altering the habitats in which wild animals dwell. Host competence, or the propensity to generate infection in another individual, is determined by behavioral and physiological traits that mitigate exposure to and the ability to cope with infectious organisms. Here, we asked whether light pollution, which inflicts hormonal dysregulation, altered immune responses, and corresponding organismal fitness loss in other species, affects avian host competence for West Nile virus (WNV). Although house sparrows (a competent reservoir species for WNV) did not experience hormonal dysfunction in response to light pollution, light pollution caused sparrows to maintain WNV titers above 10^5 PFU (the transmission threshold to biting mosquitoes) for 2 days longer than controls. Light pollution also had no effects on tolerance of infection (i.e., the ability of individuals to maintain body mass when infected) or WNV-associated mortality. The combined effects of extended infectious duration in the absence of poor health or increased morality could exacerbate the risk of WNV emergence, persistence, and/or spillover in areas of high light pollution, which tend to occur in close proximity to human populations.

P3-70 KERNBACH, ME*; UNNASCH, TR; GERVASI, SS; MARTIN, LB; University of South Florida, Monell Chemical Senses Center; *kernbach@mail.usf.edu*
Effects of Acute and Chronic Stress Exposure on Avian Responses to West Nile Virus
Wild animals cope with both short-term (acute) and long-term (chronic) stressors. The glucocorticoid hormones, such as corticosterone (CORT), often facilitate such coping, but they can have quite distinct effects contingent on the duration of their elevation and subsequently the host cells and tissues they affect. Previously, we found that experimental elevation of CORT for 2 days affected responses to West Nile virus exposure in zebra finches (*Taeniopygia guttata*); manipulated birds had higher viremia for days longer than controls although West Nile virus (WNV)-associated mortality remained low until well after viremia had peaked. Here, we queried whether acute elevations of CORT would have similar effects or if instead elevation in just the 1h prior to exposure would instead be protective; much work in rodents has shown that short term CORT elevations can help hosts resist or cope with infection. We found that although CORT injection elevated circulating CORT to a similar degree as 2d implantation, effects on WNV outcomes were very different. Implanted individuals reached higher viremia and suffered mortality to WNV, however, the same birds were more tolerant of WNV than the other two groups and only implanted birds reached titers that could be transmitted to vectors. Our work reveals additional, yet complex, roles for CORT in avian West Nile virus dynamics.

15-5 KESSLER, BJ*; SANKO, KA; ELIAS, DO; Univ. of California, Berkeley; *benjik2013@gmail.com*
50 Shades of Prey: Plastic sensory usage in prey capture
Animals use a variety of sensory modalities to accomplish tasks necessary for survival, often using more than one modality to accomplish a given task. Spiders are capable of incredibly sensitive detection of substrate-borne vibrations, and jumping spiders in particular have the most acute vision known in arthropods. In this study we investigate how the availability of visual and vibratory information and their combination affects prey capture in the jumping spider *Habronattus formosus*. Wild-caught spiders were placed with a single prey item (either a cricket or a flightless fruit fly) in experimental arenas where we could manipulate the visual and vibratory environment. Time to capture was recorded, as was the spider's ability to capture their prey. Spiders had slower capture time and lower probability of success in dim lights and when the prey was a cricket. Lack of substrate-borne vibrations lowered the probability of success for catching crickets but not flies. Dim lights disproportionately lowered the probability of success for catching crickets. These results suggest that jumping spiders are plastic in their use of sensory information.

4-2 KETCHUM, RN*; SMITH, EG; VAUGHAN, GO; MCPARLAND, D; PHIPPEN, BL; CARRIER, TJ; BURT, JA; REITZEL, AM; UNC Charlotte, NYU Abu Dhabi , NYU Abu Dhabi; *remiketchum@gmail.com*
Microbial community dynamics of a keystone urchin species in the Persian/Arabian Gulf
Microbial communities of marine organisms have been shown to play a crucial role in the development, physiology, and thermal tolerance of their hosts. The rock-burrowing urchin, *Echinometra mathaei*, is found across the Indo-Pacific and plays a significant role in the health and dynamics of reef ecosystems as a major bioeroder. The range of *E. mathaei* extends into the thermally extreme Persian/Arabian Gulf (PAG), where present-day summer maxima (~35-37°C) exceed climate change predictions for the Indo-Pacific reefs in the next century. To date, there have been very few studies on microbial composition of marine organisms in this region and no studies that focus on the microbiome of *E. mathaei*, despite the potential role that it may play in this species' ability to survive extreme conditions. To assess the role of the microbiome in the PAG, we collected twenty *E. mathaei* from one site within the PAG and contrasted their microbial assemblage with twenty individuals from one site in the neighboring Gulf of Oman (summer maxima of ~30-32°C). *E. mathaei* living within the PAG are located at a depth of approximately 19-20ft within a coral reef ecosystem, while the individuals living in the Gulf of Oman site are located within a much shallower intertidal ecosystem (about 6-7ft). Further, we used three different extraction protocols in order to optimize our approach so that we most accurately represent the communities present. We used 16S rRNA gene amplicon sequencing to characterize the microbial assemblage at a temporal and geographic scale. Our analysis allowed us to make predictions regarding the role of the localized microbial assemblages, and assess the best methodology for future research endeavors.

P1-56 KHALIL, HH*; TUTWILER, AY; MAY, LA; AWALI, S; BELANGER, RM; University of Detroit Mercy; *khalilhh@udmercy.edu*

Atrazine Exposure Affects Olfactory Sensory Neuron Morphology in The Lateral Antennules of Crayfish (Orconectes virilis)

Atrazine is one of the most commonly used herbicides in the United States. Previous work has shown that exposure to atrazine negatively affects crayfish chemoreception, a physiological process essential to detecting food and mate odors. Our past research has also shown that after being exposed to clean water for a 72-hour period, crayfish do not recover their chemoreception abilities short term. Current data suggests that atrazine exposed crayfish are able to recover long term, regaining chemoreception within 15 days post-atrazine exposure. Due to the fact that atrazine impairs chemosensory responses, our goal for this study was to determine the effect of atrazine on olfactory sensory neurons located in the lateral antennules of crayfish. In this experiment, two groups were utilized. One group was exposed to environmentally relevant concentrations of atrazine, which included concentrations of either 80 ppb or 300 ppb respectively, for a 15-day period. The second group served as the control and was withheld from atrazine exposure. Post treatment, lateral antennules from both groups were fixed in 4% paraformaldehyde, decalcified and subsequently cryoprotected. Medial segments were then sectioned on a cryostat. Antennule cross sections were stained with antibodies against tubulin, a protein found in neurons, and DAPI, a nuclear stain and imaged. Our data shows that atrazine exposure causes degeneration of olfactory sensory neuron bundles or clusters, leading to impairments in chemosensory abilities. Overall, this research demonstrates that environmentally-relevant atrazine exposure causes structural changes in the main olfactory organ of crayfish. Future research will allow for the examination of olfactory cell death and regeneration.

P2-91 KHALIL, S*; WELKLIN, JF; MCGRAW, KJ; WEBSTER, MS; KARUBIAN, J; Tulane Univ., Cornell Univ., Arizona State Univ., Tulane Univ. ; *skhalil@tulane.edu*

Exploring the Link Between Circulating Carotenoids and Signal Expression in the Red-backed Fairywren

Carotenoid-based signaling is a classic example of honest signaling, in that acquiring or metabolizing carotenoids imposes costs such that those individuals expressing the most carotenoid rich signals are in the best condition. The red-backed fairywren (RBFW: *Malarus melanocephalus*) provides an interesting system in which to refine our understanding of the potential costs and mechanisms of the expression of carotenoid-based signals. In this species, males within a single population exhibit flexible reproductive phenotypes, where some males express red-black plumage that includes a sexually-selected vibrant red feather patch on their back, and other males exhibit a plumage identical to brown females, lacking the red patch. Previous work has shown that brown males are able to produce carotenoid based plumage within days of switching social status from subordinate helpers to dominant breeders. However, it remains unknown whether RBFW males maintain high levels of circulating carotenoids even when brown, or whether they only increase carotenoid levels when molting into red-black plumage. Established theory predicts that male carotenoid levels should be highest during molt, and low outside of the molt period because producing carotenoid coloration is costly. We tested this prediction by quantifying plasma carotenoid levels in brown males, red-black males and females. Preliminary evidence indicates that plasma hue of brown males more closely resembles that of red-black males, suggesting that there may be low costs of obtaining or metabolizing carotenoids in this system. Our findings highlight the complex ways in which carotenoids may be used to signal quality and set the stage for future research in this system.

P3-93 KHAN, NY; WROBEL, ER*; NAVARA, KJ; University of Georgia; *ewrobel@uga.edu*

Comparing the effects of beeswax versus silastic testosterone implants on elevation of plasma testosterone and reproductive condition in laying hens

Practices involving the experimental alteration of hormone concentrations have been widely used to study how hormones influence behavior and physiology. In birds, silastic implants are the most commonly used method of elevating circulating hormones over a long-term period. However, silastic implants have a series of drawbacks; the amount of hormone that the implant releases into the body can be inconsistent, the implantation method requires minor surgery and stitches to keep the implant in place, and the implants need to be removed from the animal when the study ends. Previous studies in quail and others suggest that made of beeswax offer a less-invasive option, as the hormone concentrations are more precise, and the implant itself melts within the body, eliminating the need to retrieve the implant at the end of a study, however these have not been tested widely in other systems or with other hormones. In this study, we aimed compared hormone concentrations in laying hens after implanting them with testosterone propionate in either beeswax or silastic implants. For the beeswax implants, we generated beeswax pellets containing 1mg, 5mg, or 10mg of testosterone propionate. For silastic implants, we filled 1/4, 1/2, or 1-inch lengths of tubing (.095 nm inner diameter) with testosterone propionate. All implants were inserted subcutaneously in the neck region of the birds. We took blood samples prior to inserting the implants and every 3d after for two weeks, and then measured testosterone concentrations via ELISA. We also recorded egg-laying patterns and overall reproductive conditions of the hens. Overall, this study yields new information on whether beeswax implants represent a more efficient alternative for experimentally elevating hormones.

38-1 KHANDELWAL, P C*; SHANKAR, C M; HEDRICK, T L; UNC, Chapel Hill, ARRS, India; *pranavk@live.unc.edu*

Take-off biomechanics in gliding lizards

Gliding animals undertake a series of complex aerodynamic and morphological adjustments in order to execute a transition from perching or resting to gliding. Take-off requires the animal to generate adequate thrust, deploy its wing and correct its body orientation immediately after launching itself towards the landing target. In order to accomplish this, the animal uses a combination of limb and tail movements along with dynamic wing and body morphing. We used two cameras recording at 240 Hz to film take-offs in a wild population of flying lizards, *Draco dussumieri*, from vertical tree surfaces for a glide distance of 5.5 m. We tracked body points including the head, limbs, wings, posterior end and tail in 3D to study take-off biomechanics in the field. Take-off was initiated by the lizard rotating from a vertical to horizontal position on the tree trunk and using its hind limbs to thrust itself in the direction of the landing tree accelerating at ~9 ms^{-2} and reaching a velocity of ~2.5 ms^{-1} by the time of complete wing deployment. Dracos are unique among gliding animals in possessing a head-mounted canard along with a main wing membrane which is supported by ribs on either side. Deployment of the canard and main wing began immediately after launch with canards being fully extended first at ~0.05 s followed by wing in ~0.10 s. The main wing was extended and held in position independently of the limbs during take-off. The forelimbs were extended from the body and eventually held parallel to the leading edge of the wing with the wrists resting on its top surface, potentially forming a leading edge slot. We observed pronounced tail movement during the take-off phase along with changes in body roll, pitch and yaw suggesting a role in controlling body orientation. These observations provide a first detailed look at Draco take-off in a natural setting.

P1-269 KHOUJA, S*; EDIE, S; COLLINS, K; JABLONSKI , D; The University of Chicago ; *safia@uchicago.edu*

Bivalves Unhinged: Hingeplate Morphology and Lifestyle in the Veneridae

Hinges enable bivalves to perform the imperative motion of opening and closing the paired valves, while resisting shear and predation. Although almost all members of the bivalve family Veneridae are burrowers or borers, a spectrum of feeding, mobility, and substrate categories can be found within the family. The diversity in hingeplates across the venerids echoes the functional variety that defines this large family. Despite the biomechanical importance of the hinge, its great complexity has made it difficult to analyze in a morphometric framework. New technologies, including micro computed tomography (microCT) and three-dimensional morphometrics, have allowed us to quantify the form of the bivalve hingeplate, specifically focusing on the "toothbank" (i.e. the region of the hinge containing the primary dentition in the form of the cardinal teeth). Our preliminary results reveal biomechanical trends among hingeplate shape, tooth structure, and tooth "topography"; venerid species that share lifestyle characteristics, specifically burrowing categories, share hingeplate and toothbank morphologies. For example, shallow burrowers such as *Chione elevata* tend to have relatively thicker cardinal teeth and wider hingeplate sockets than faster deeper burrowers like *Macrocallista nimbosa*. Overall, we discovered that these biomechanical trends correlate more strongly to ecological categories than taxonomic groupings.

P1-61 KHOURY, M.*; ZUEVA, O.; MASHANOV, V.; Univ. of North Florida; *n00978919@ospreys.unf.edu*

Notch Signaling is Required for Brittle Star Arm Regeneration

The Notch signaling pathway plays a key role in metazoan development. While the role of this pathway in development is quite clear, the functional significance of it in regeneration, the process of regrowing lost or damaged body parts, is unknown. Therefore, the focus of this study is to determine the function of the Notch signaling pathway in regeneration. We used as our study system the brittle star *Ophioderma brevispinum* (Echinodermata, Ophiuroidea), which is capable of autotomizing its body appendages (arms) and quickly growing them back. To determine the role of Notch signaling in regeneration, we used the pharmacological agent N-[N-(3,5-Difluorophenacetyl)-L-alanyl]-S-phenylglycine t-butyl ester (DAPT, 3 µM, 14 days) to continuously inhibit the pathway in regenerating animals and then examined the effect of the inhibition at the morphological and cellular levels. Our results showed that arm regeneration was significantly impaired in the DAPT-treated animals as compared to the control group, resulting in a 38% reduction in the length of the outgrowth (Student's t-Test, P=0.01). We are currently investigating which cellular processes (cell proliferation, apoptosis, cell differentiation) are regulated by the Notch pathway. In the future, we plan to expand this study by conducting an RNA-Seq analysis to determine the specific genes that are regulated by this pathway in regeneration. Overall, our data indicate that Notch signaling is required for arm regeneration in the brittle star *O. brevispinum*.

P2-18 KHURSHID, S*; ZIAUDDIN, L; HALL, IC; Benedictine University, Lisle IL; *ihall@ben.edu*

Endocrine regulation of reproduction in amphibians

The endocrine mechanisms regulating reproductive behavior vary across species. Comparative differences in the effects of hormones can be due to differences in life history. In certain urodele amphibians, prolactin can be used to induce and maintain sexual receptivity. Urodele reproduction typically involves the transition from a terrestrial to an aquatic environment. In contrast, African clawed frogs, *Xenopus laevis*, are fully aquatic anuran amphibians. *Xenopus* typically spend their entire lives in murky ponds and mating occurs primarily at night, thus *Xenopus* use vocal communication to locate potential mates. We investigated whether prolactin would induce sexual receptivity in *X. laevis* by measuring advertisement calling after prolactin injection. While prolactin did not induce advertisement calling, it did cause the molting of the cornified layer of the skin. Prolactin acts as an osmoregulatory hormone in many vertebrates, and our findings suggest that the role of prolactin in urodele reproductive physiology and behavior may have evolved because of a coincidental change in osmoregulatory needs that occurs when the newts must adjust to an aquatic environment for mating. In *X. laevis*, which do not move from terrestrial to aquatic environments in order to mate, prolactin does not induce reproductive behavior but still appears to play a role in osmoregulation. Further research is needed to determine the effects of prolactin on the skin.

6-3 KIENLE, SS*; HERMANN-SORENSEN, H; COSTA, DP; REICHMUTH, C; MEHTA, RS; Univ. of California, Santa Cruz; *skienle@ucsc.edu*

Comparative feeding strategies and kinematics in phocid seals

The feeding behaviors and kinematics of captive bearded seals (*Erignathus barbatus*), harbor seals (*Phoca vitulina*), ringed seals (*Pusa hispida*), and spotted seals (*Phoca largha*) were characterized through controlled feeding trials. All species primarily used a suction feeding strategy but biting was also observed, specifically pierce feeding. Suction and pierce feeding behaviors were relatively consistent across all four species. Suction feeding was kinematically distinct from pierce feeding and was characterized by significantly faster feeding event times, smaller gape and gape angles, smaller gular depressions, and fewer jaw motions. Most species showed higher variability in suction feeding performance, indicating that suction is a behaviorally flexible feeding strategy. Bearded seals exhibited the fastest feeding event times, largest gapes, and fewest jaw motions, providing further support for their classification as suction feeding specialists. Although harbor, ringed, and spotted seals are classified as pierce feeders based on skull and dental morphologies, behavioral and kinematic analyses reveal that these species are able to generate suction for prey ingestion. Our comparative study therefore indicates that skull morphology may not reflect the true diversity of feeding behaviors used by pinnipeds. The ability of all four species to use multiple feeding strategies is likely advantageous for these marine carnivores foraging in spatially and temporally dynamic marine ecosystems.

P3-259 KIGHT, H*; GEORGE, S; Georgia Southern University; *georges@georgiasouthern.edu*

Are varying characteristics of saltmarsh sediments contributing to differences in protein content of juvenile fiddler crabs?

Salt marshes provide many natural services that directly or indirectly affect our everyday lives. Understanding their complex systems is essential in sustaining those services and maintaining our livelihood. The mussel, *Geukensia demissa*, and fiddler crab, *Uca pugnax*, are facilitator species that increase the organic content of salt marsh sediments. In a local salt marsh at Tybee Island, Georgia, mussels are primarily found on raised portions of the substrate referred to as mounds and rarely on mudflats. Mounds tend to be common between the lower high marsh and the low marsh. They attract a variety of species including mud crabs, small box crabs, and juvenile and adult fiddler crabs. This study investigated whether higher organic content of the sediment on mounds lead to greater abundance and higher protein content of juveniles compared to off-mound sites. Four mound and 4 off-mound sites were flagged and the number of juvenile burrows, adult burrows and tunnels counted, and the heights of 10 *Spartina* stems recorded in the Summer of 2016 and Spring 2017. Sediment cores for organic content analysis and 10 juvenile fiddler crabs for protein determination were collected from each site. It was found that juvenile fiddler crabs are much more abundant on mounds than off, and that mounds have more silt-clay sediments than off mound sites. Protein content of juveniles was significantly higher in September than in October 2016 but did not differ on and off mounds. Variation in sediment nutrient content on and off mounds over time might contribute to differences in juvenile fiddler crab abundance and overall fitness.

97-5 KIKUCHI, D*; MAEDA, M; SHIOMI, K; TANAKA, H; Tokyo City Univ., Tokyo Institute of Technology, National Institute of Polar Research; *dale.kikuchi@gmail.com*

Not ornament but aerodynamic device? New hypothesis for the horn of rhinoceros auklet

It has long been debated that morphological trait appears only in breeding season (i.e. ornament) is evolved through sexual selection. On the other hand, there are ornament-like traits whose evolutionary reasons are difficult to be explained solely by the theory of sexual selection. One such example is the horn of rhinoceros auklet (*Cerorhinca monocerata*, a seabird species), which appears on the top of beak in both male and female only in breeding season. It is reported that there are no sexual differences in size of the horn. In addition, a protruding object like the horn on a flying animal would increase aerodynamic or hydrodynamic drag (retarding force) and hence the energetic cost of locomotion. To date, no one has yet suggested a plausible function of the horn of rhinoceros auklet. In fact, there are some cases where a protruding object can reduce aerodynamic drag. For example, a vortex generator, a small plate attached on the surface of an aircraft, affects the airflow downstream of it and reduces drag. Moreover, in the breeding season of rhinoceros auklets, both male and female fly with a bunch of small fish for feeding chicks, which would cause substantially large drag. Taken together, we hypothesized that the horn of the rhinoceros auklet may have the similar role of vortex generator, particularly when the bird flies with fish in its beak. In order to test our hypothesis, we used computational fluid dynamics (CFD) technique to simulate the airflow around the bird, and compared the flow-field and drag force among the presence/absence of horn and fish. We will report the aerodynamic phenomenon and the drag reduction effect due to the horn.

106-4 KIMMITT, A.A. *; KETTERSON, E.D.; Indiana Univ., Bloomington; *akimmitt@indiana.edu*

Differences in Female Reproductive Timing May Contribute to Divergence in Seasonally Sympatric Populations

Animal migration can lead to a special case of population distribution known as seasonal sympatry, in which closely related migrant and resident populations occur in sympatry during winter, but are otherwise allopatric. Residents may initiate breeding prior to the departure of migrants, which could allow interbreeding. Alternatively, early departure of migrants and population differences in reproductive timing may prevent gene flow. Male dark-eyed juncos from seasonally sympatric populations are known to differ in timing of reproductive development as migrants lag behind residents in gonadal growth. Far less is known about female differences in reproductive timing. We caught 18 migrant and 15 resident female juncos early in the breeding season of the resident population (March-April) and collected ovarian tissue to compare expression of genes associated with reproduction using qPCR. We found that residents had significantly larger ovaries than migrants ($p < 0.001$). We further found that resident ovaries may be more sensitive to luteinizing hormone (LH) than migrant females because mRNA transcripts for LH receptor were more abundant in residents ($p=0.004$). Transcript abundance for other receptors associated with reproduction, however, did not differ between populations. We also asked whether gene expression varied among migrants in relation to their migratory distance as estimated from feather isotope data. We conclude that migrant and resident females differ in timing of reproductive development, that gene expression for receptors associated with reproduction may explain some of the difference, and that reproductive timing in females may serve as an isolating mechanism to prevent interbreeding between resident and migratory populations.

3-7 KIMURA, H*; KAWABATA, Y; Nagasaki University, Nagasaki, Japan; *h.kimura787@gmail.com*

Effect of initial body orientation on escape probability in prey fish escaping from predators

When exposed to predators, most juvenile fishes exhibit escape response, which is composed of a swift initial turn and forward acceleration. A large number of studies have been conducted on the relationship between the components of escape response (e.g. flight initiation distance, prey speed) and escape probability; however, the relationship between prey's body orientation relative to a predator at the onset of the escape response (initial orientation) and escape probability remains unclear. The initial orientation could be crucial for escape response, because prey's sensory perception range can have spatial bias, and the turn duration before the initiation of escape locomotion can be smaller when the initial orientation is more away from the predator. We tested this hypothesis by recording the escape responses of juvenile red sea bream (*Pagrus major*) in response to the predatory scorpion fish (*Sebastiscus marmoratus*). Escape probability was higher when the flight initiation distance was larger. If the effect of flight initiation distance was offset, escape probability was higher when the initial orientation was more away from the predator. The flight initiation distance tended to be small when the prey was attacked from behind, compared to when attacked from front and side. The turn duration was smaller when the initial orientation was more away from the predator. These results suggest that the initial orientation affects escape probability through 2 pathways: flight initiation distance and the turn duration. These findings highlight the importance of incorporating initial orientation into other studies of the kinematics of predator-prey interactions.

P1-78 KIN, K*; BAIOCHHI, T; DILLMAN, A; Univ. of California, Riverside; *kkin001@ucr.edu*
Dispersal vs. Repulsion: Prenol elicits diverse behavior in Entomopathogenic Nematodes
Entomopathogenic nematodes (EPNs) are parasites that are able to kill insect pests and are widely used as biological control agents. During their lifecycle, EPN infective juveniles (IJs) leave their resource-depleted cadaver, and use chemosensory cues to locate a new host. Prenol is an odorant associated with already-colonized, resource- deficient hosts. To evaluate prenol as a dispersal cue, four species of EPNs from the family *Steinernema* were tested to identify if the odorant increased dispersal behavior in IJs across varying ages. Additionally we evaluated two types of assays- one aimed specifically at gauging dispersal and the other aimed at evaluating general chemotactic behavior. The viability of prenol as a dispersal cue varied between species and across the time points tested:4 hours, 24 hours, and 7 days post emergence from insect cadavers. We found that EPN IJs respond in a species-specific manner to prenol. Prenol increased dispersal behavior at 4 hours post collection for all species tested with the exception of *S. riobrave*, indicating that EPNs differ in their susceptibility to dispersal cues. At 24 hours post emergence, prenol acted as a viable dispersal cue for all species except *S. feltiae*, demonstrating that time post emergence affects dispersal. By 7 days post emergence, prenol's ability to elicit IJ dispersal was weakened for all of the species tested expect *S. carpocapsae*. This may indicate that while *S. carpocapsae* is repelled by prenol, it may not be involved in dispersal behavior for this species. While the effect of prenol as a dispersal cue differed between species and were age dependent, repulsion behavior was fairly consistent between species and time post emergence. The difference suggests that our assays really are measuring different behaviors, and may assist in efforts to better utilize EPNs as biological control agents.

P1-74 KING, T/P*; TRAMONTANA, B; MARUSKA, K/P; Louisiana State Univ.; *tking21@lsu.edu*
Behavior and neural activation patterns of non-redundant visual and acoustic signaling during courtship in an African cichlid fish
Animals live in a multisensory world and use different sensory channels to communicate during crucial behavioral contexts such as aggression and reproduction. Despite the importance of multimodal communication, there are relatively few species in which information on sender signals and receiver responses are known. Further, little is known about where in the brain context-dependent unimodal and multimodal information is processed to produce adaptive behaviors. Dominant male African cichlids, *Astatotilapia burtoni* , produce low frequency sounds during their visual courtship quiver displays directed towards receptive females, providing an ideal system to examine multimodal signaling from both behavioral and neural perspectives. We quantified affiliation behaviors and neural activation patterns in gravid females that were exposed to visual, acoustic, and visual-acoustic signals from courting dominant males. Females showed similar affiliation behaviors during visual and visual-acoustic conditions, but affiliation was reduced in acoustic only trials. These different female receiver responses in each unimodal signal condition indicates that visual and acoustic signals are non-redundant (convey multiple messages) in this reproductive context. Similar affiliation responses in visual only and visual-acoustic trials indicate that visual information dominates acoustic. Using the neural activation marker cfos, we also identified differential activation in specific socially-relevant brain nuclei between unimodal and multimodal conditions. Combined with our previous work on chemosensory signaling, we propose that *A. burtoni* represents a valuable vertebrate model for studying context-dependent behavioral and neural decision rules associated with non-redundant multimodal communication.

81-3 KING, H*; OCKO, S; MAHADEVAN, L; University of Akron, Stanford University, Harvard University; *hking@uakron.edu*
Solar-powered ventilation in African termite mounds
The complex mound architectures of certain species of social termite have long been associated with passive, internal climate control function, while existing theories pointed to different specific mechanisms and driving forces, such as wind and metabolic activity. Recent, direct measurements of their internal temperature and flow patterns suggest that the mounds of Odontotermes obesus of South Asia harness instead diurnal oscillations in ambient temperature for driving circulation between subterranean nest and the mound above, a crucial step in their colonial respiratory function. Subsequent study of Macrotermes michaelseni, in Southern Africa, reveals the same general mechanism: circulating flow driven by transient thermal gradients; despite significant differences in environmental conditions and mound morphology. In contrast with the more shaded Asian mounds, however, thermal gradients in the African mounds appear to be directly influenced by the motion of the sun in the sky, adding a solar-powered component in the flow pattern. CO_2 measurements additionally show that African mounds are better mixed throughout day and night, suggesting that their respiratory function is limited by diffusive exchange across the mound wall rather than internal circulation, unlike that of the Asian mounds. The fundamental dependence on transient forcing for passive ventilation, displayed by both mounds, have natural implications for human engineering.

71-6 KING, EE*; STILLMAN, JH; WILLIAMS, CM; Univ. of California, Berkeley; *emily_king@berkeley.edu*
Metabolic Response to Progressive Hypoxia in an Invasive Freshwater Snail
Invasive species often have physiological traits that allow them to survive potentially harsh conditions of transport to new locations. *Potamopyrgus antipodarum*, a worldwide invader of fresh and brackish water habitats, can close its shell to wait out unfavorable conditions during transport, a trait that likely increases survival but subjects it to hypoxia. This study investigates the effect of water temperature and oxygen content on oxygen consumption rates to understand if this snail regulates or conforms to ambient oxygen conditions as a mechanism to survive stressful transport conditions. Oxy-regulators have the ability to maintain their respiration rates while the oxygen concentration decreases, while oxy-conformers reduce their respiration rates with decreasing oxygen levels. We hypothesized that this snail would be a conformer as are some other aquatic invasive species. Oxygen consumption was measured during progressive hypoxia and metabolic rate calculated relative to ambient oxygen concentration to test for regulation versus conformity. Respiration rate decreased with decreasing oxygen concentration for all measurement temperatures suggesting that these snails are oxygen conformers and that this strategy is not temperature dependent. Decreased respiration rates may signal a shutdown of metabolic processes during hypoxia, thus allowing snails to wait out stressful conditions on limited oxygen supplies by conforming. This strategy for surviving oxygen limitation is a trait that may lead to increased invasiveness for some species.

112-7 KING, R.W.; Clark University, Worcester MA;
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Paleohabitat Modeling of Marine Threespine Stickleback Glacial-Age Refugia
During the last glacial maximum, the Cordilleran Ice Sheet covered mainland British Columbia including much of Vancouver Island. Sea level was 125-145m below the present level, creating ice-free habitats on the low-slope continental shelf where estuaries develop. Thus, there likely existed a zone of refugia for marine, anadromous, and possibly freshwater species along the coast. The conventional model of post-glacial evolution in freshwater threespine stickleback (*Gasterosteus aculeatus*) assumes independent colonization of many lakes from a relatively uniform oceanic ancestor. However, extant oceanic populations around Vancouver Island vary in frequency of morphological traits, and trait distributions map well on sea surface salinity variation. Here we use a GIS approach to map glacial retreat and relative sea level change to model estuary development from 25,000 yr ago to the present using an adjusted sea level curve. We infer relative surface salinity changes from broad glacial melt patterns. The resulting time series of habitat development, migration, and loss suggests two general colonization routes for refugial Pacific Ocean populations into recently-deglaciated watersheds; the southern group via the low-salinity Salish Sea and the northern group via the high-salinity LaBouchere passage. If adequate estuarine habitat existed through the last glacial maximum, ancestral stickleback populations from two geographically, and possibly genetically, distinct sources were likely colonizers of freshwater habitats, rather than a single genetically uniform ancestral population as is often assumed. This could account for some apparent variation among both oceanic and freshwater populations on Vancouver Island.

9-8 KINGSOLVER, J.G.*; UMBANHOWAR, J.; Univ. of North Carolina, Chapel Hill; *jgking@bio.unc.edu*
The analysis and interpretation of critical temperatures
Critical temperatures are widely used to quantify the thermal limits of organisms. But measured critical temperatures often vary with methodological details such as starting temperature and ramping rate, leading to spirited discussions about the effects of stress and acclimation during the experiments. We illustrate the statistical reasons why methodological details affect observed values of critical temperature, independent of stress or acclimation. We develop a statistical model that estimates a failure rate function (the relationship between failure rate and current temperature) using maximum likelihood; the best model accounts for 58% of the variation in CT_{max} in an exemplary dataset for tsetse flies. Our results reject the interpretation of CT_{max} as a stepwise, threshold temperature. We then extend the model to incorporate potential effects of stress and acclimation on the failure rate function, and apply the model to two insect datasets. The results show how stress accumulation at low ramping rates may shift the failure rate function, decreased observed values of CT_{max} (tsetse flies); and how acclimation (heat-hardening) may reduce the slope of the failure rate function, increasing observed values of CT_{max} (hornworm larvae). The model provides a new approach to analyzing and interpreting critical temperatures.

54-3 KINGSTON, ACN*; CHAPPELL, DR; SPEISER, DI; University of South Carolina; *acnahm@gmail.com*
Molecular, Structural, and Functional Complexity of the Sensory Organs of Chitons
Chitons (Mollusca: Polyplacophora) display a diversity of sensory structures embedded within their eight overlapping shell plates. All chitons have non-pigmented clusters of multimodal sensory cells called aesthetes. In addition to aesthetes, some chitons have image-forming eyes. Still other chitons have modified aesthetes that include an eyespot with a pigmented retina-like structure. To ask how eyes and eyespots may have evolved from aesthetes, we examined the relationships between the molecular, structural, and functional complexities of these sensory organs. We studied molecular and structural complexity by comparing the expression of molecular components of sensory transduction in chitons that represent each character state: a chiton with aesthetes, a chiton with modified aesthetes that include eyespots, and a chiton with aesthetes and eyes. We learned that aesthetes express many molecular components of sensory transduction; that the retina-like structures of eyespots express a subset of the proteins found in aesthetes; and that the photoreceptors in the eyes express fewer molecular components of sensory transduction than aesthetes and eyespots. To address the relationship between structural and functional complexity, we tested how chitons with eyespots respond to changing overhead stimuli and static visual landmarks. Like all chitons, those with eyespots respond to changes in the overhead light field. However, in contrast to chitons with eyes, chitons with eyespots do not distinguish between objects and equivalent, uniform changes in light levels. We also found that chitons with eyespots have the ability to orient to static visual landmarks. We conclude that the eyespots of chitons may represent molecular and structural intermediates between aesthetes and eyes, but they do not appear to represent functional intermediates.

90-3 KINNUNEN, RP*; SCHMIDT, C; GARROWAY, CJ; University of Manitoba, Winnipeg, Canada;
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City Traits as Predictors of Avian Diversity and Life History Traits
Given the increasing pace of urbanization globally, conservation managers and ecologists need to learn about the responses of animal populations to features of cities if measures to conserve biodiversity are to be successful. We cannot study the responses of all species to urbanization- however, shared life history traits of successful urban species will give insight into how species might be affected by urbanization in general. Our goal was to link urban avian biodiversity and species life history traits to the features of cities within which they occur. To do this we first quantified the diversity of urban birds (Christmas Bird Counts) and their life history traits (e.g., body mass, clutch size). We then used spatially explicit modelling to ask which geographic and socioeconomic features of cities (20 cities with population size > 500.000) in the U.S. and Canada predicted biodiversity and life history traits. By identifying links between city features and the diversity and life history traits of those doing well in cities, we will be better able to predict the consequences of continued urban expansion. Our analyses will provide much needed information about the impacts of human disturbance on biodiversity and provide insight into the life history traits that foster persistence after rapid environmental changes.

P3-147 KINSEY, CT*; MCBRAYER, LD; Georgia Southern University; *ck03480@georgiasouthern.edu*

Morphological Variation as a Function of Habitat Preference in Phrynosomatid Lizards

Often, a predictable relationship exists between an organism's habitat and its locomotor biomechanics. Lizards use a range of vertical and horizontal substrates (e.g. arboreal, or terrestrial habitats) where selection is expected to optimize morphological and functional performance on their dominate substrate type. Thus, studying the functional evolution of the axial skeleton aids our understanding of the degree of coupling between phenotypic variation and various habitats or locomotor modes. This study quantified the variation of scapular shape across 28 lizard species that vary across four substrate types. A lateral view of the scapula was photographed from specimens. Pictures were imported into MorphoJ along with a pruned phylogeny. Specimens were coded by substrate (terrestrial, arboreal, saxicolous, or generalist) to perform a canonical variate analysis of scapular shape in light of phylogenetic history. Using a Brownian motion model of evolution, minimal phylogenetic signal was detected, however additional models will be examined. The width of the articulation between the suprascapula and scapula accounted for 56% of the shape variation, while scapula height accounted for 28.6% of the variation. The scapular shape of terrestrial lizards was significantly different from arboreal and generalists, while saxicolous was intermediate in morphospace. Terrestrial locomotion likely generates the basal condition, but newly invaded substrates may lead to a shift in scapular shape. The lack of phylogenetic signal, coupled with distinct separation in terrestrial lizards, suggests that scapular shape responds to the functional demands of locomotion on particular substrate types within this clade.

67-4 KINSEY, CT*; MCBRAYER, LD; Georgia Southern University; *ck03480@georgiasouthern.edu*

The Role of Forelimbs in Bipedal Running Lizards

Many lizards are capable of bipedal locomotion via high acceleration and/or posterior shift in body center of mass (BCoM). Kinematic analyses to date have focused primarily on the role of hindlimbs in generating power and acceleration. Yet forelimb position, which may affect a shift in BCoM, has yet to be studied in the context of bipedalism. This study quantified forelimb positions when transitioning to and from a bipedal posture at the start of a sprint and when crossing an obstacle. Change in BCoM from varying forelimb positions was also quantified. Two species with contrasting body forms (and thus different BCoM) were studied (*Sceloporus woodi*, *Aspidoscelis sexlineata*) to assess potential variation due to body plan and obstacle crossing behavior. Lizards were coerced to run along a 1.4-meter track with an obstacle present and filmed with high speed video. A subset of lizards was euthanized and BCoM was measured. Four commonly used forelimb positions were noted during bipedal running: gait cycle, cranial extension, cranial flexion and adduction, and caudal extension. When transitioning to a bipedal posture at an obstacle, *S. woodi* primarily held their forelimbs in a cranially flexed and adducted position. Caudal extension of the forelimbs was primarily used by *A. sexlineata* when transitioning to a bipedal posture. Both species primarily used a gait cycle when transitioning to a quadrupedal posture. *Aspidoscelis sexlineata* has a more posteriorly shifted BCoM (9.13mm ±0.78) than *S. woodi* (12.87mm ±0.55). Caudally extended forelimbs shifted the BCoM (0.66mm ±1.53) further posteriorly. Thus, forelimb position aids transitions between bipedal and quadrupedal posture by shifting the BCoM, and these patterns appear to be stereotyped for some species.

S4-4 KIPNIS, Anna; Double Fine Productions; *anna.kipnis@gmail.com*

Communication through Playful Systems: Presenting scientific research the way a game might do

More than ever, Science is in the unenviable position of competing for the hearts and minds of the public against utterly false accounts of our world. These false accounts are often deeply spiritual, poetic, sublime — despite being false, they can leave a mark on the human imagination. It is difficult to convey scientific research in a way that leaves the audience with a comparable sense of awe or a personal connection to the subject matter. This is an area where the games medium can offer some assistance and insight. A game can convey its complex inner workings with ease by engaging an audience through play. It is expressive communication that sows intuitive understanding and fosters a personal connection between the human player and the represented world. Games like Minecraft and Portal are thus increasingly being used in classrooms to teach math, physics, spatial reasoning, and even the scientific method. I discuss the process of designing interactive experiences in games as a model for effective communication. Drawing on examples from my own work at Double Fine Productions, I offer insights from game design to address parallel challenges in scientific communication. I explore ways of introducing an audience to an unfamiliar world through narrative and play. For example, by setting up the rules of an unfamiliar world in an interactive way, especially through iterative problem solving, you can lead a novice audience to a nuanced understanding of that world's complexity without overloading information. These strategies can enhance communication of scientific research in any format.

25-2 KIRCHER, BK*; COHN, MJ; Univ. of Florida; *kircherb@ufl.edu*

Growing apart: characterizing the development of sexual dimorphism

Species vary widely in their pattern and magnitude of sexual dimorphism, yet the proximate mechanisms that regulate these differences remain poorly understood. Sexually dimorphic characters present special challenges to our understanding of anatomical evolution because the sexes share the majority of their genomes yet can diverge in size, shape, and anatomical characters during development. Lizards in the genus *Anolis* (anoles) are an often-used model for evolutionary studies of sexual dimorphism and are also an emerging model for comparative developmental analyses. An example of a sexually dimorphic trait in *Anolis* is the dewlap, a colorful throat fan that is usually larger in males than in females and is used frequently by males (but infrequently by females) during courtship and aggression. Located on the throat and extending down the belly, the dewlap is supported by the second ceratobranchial cartilage (C2) in the hyoid system. We investigated the developmental basis of the sexually dimorphic dewlap apparatus in anoles and identified differences in C2 development between males and females that suggest sex-specific regulation of early skeletogenesis.

137-1 KISSANE, K/C; COLLEGE, Blinn; Blinn College; *kelly.kissane@blinn.edu*

The effectiveness of interleaving lessons in undergraduate biology courses.

Undergraduate sciences courses have traditionally been taught in a linear, chapter based modules. Recent evidence, however, has indicated that students retain more by learning in an interleaved format. An interleaved format allows students to compare and contrast material from different chapters, reducing confusion about terms and concepts that may seem similar if taught in a linear way. Quizzes that involve questions from several different chapters rather than just one chapter were utilized in two different majors level general biology courses. Here I present the results comparing students' test scores in traditional versus interleaved formatted courses.

P3-269 KITCHEN, SA*; VON KUSTER, G; MILLER, W; BAUMS, IB; Penn State Univ.; *sak89@psu.edu*

STAG: Standard Tools for Acroporid Genotyping

Acropora cervicornis and *A. palmata* are listed as threatened under the US Endangered Species Act as a result of massive population declines in recent decades. This loss is attributed in part to increased disease prevalence, bleaching events and anthropogenic disturbances. Restoration efforts are underway that aim to increase or at least maintain genotypic diversity of these species. High-resolution genetic tools are required for this task because acroporids frequently occur as large clonal stands that can only be delineated via genotyping. Previously, species-specific microsatellite markers were used to resolve *Acropora* genotypes and while these markers provided reliable results they are difficult to implement for restoration practitioners without access to a genetics laboratory. We thus have identified biallelic single nucleotide variants (SNV) markers from deep- and shallow-sequenced *A. cervicornis* and *A. palmata* genomes to genotype individuals, distinguish populations and hybrid states. From these markers, we developed a custom SNV array using Affymetrix Axiom genotyping technology. We applied this array to 150 archived samples. The resulting SNV genotyping data is then analyzed using an open access Galaxy-based web portal, Standard Tools for Acroporid Genotyping (STAG), to perform an automated, standardized bioinformatics protocol to obtain genotypes. User supplied data can then be compared to the online database of all previously genotyped samples providing the user with information on previous observations of their genotypes including sampling location, collection date and hybrid status. The SNV array combined with STAG will allow for reliable, standardized identification of host genotype information. The publically available database of Acroporid genotypes can then be used for the definition of management units based on genetic differentiation among genets, sites, populations, and species.

20-7 KITCHEN, SA*; RATAN, A; MILLER, W; BAUMS, IB; Penn State Univ., Univ. of Virginia; *sak89@psu.edu*

Genome synteny, divergence and introgression between Caribbean Acroporids

Reef-building corals are currently threatened by rapid changes in local and global stressors and hybridization offers a potential shortcut for rapid adaptation and evolutionary rescue in these species. The sympatric corals *Acropora palmata* and *A. cervicornis* form the hybrid, *A. prolifera*, whose abundance has continued to increase, either through fragmentation or sexual reproduction, while the parental species decline. Previous work indicates that weakened prezygotic isolation mechanisms in *A. cervicornis* but not *A. palmata* could allow for continuous unidirectional gene flow between the two species. Furthermore, asymmetric introgression from *A. palmata* to *A. cervicornis* has been recorded in three nuclear loci. In contrast, we found evidence for backcrossing with *A. palmata* across three hybrid zones although the frequency of hybrids and backcrosses differs across the range. Here we used genomic sequence data from the two parental species and their hybrids to further characterize the patterns of genomic synteny, divergence and introgression across three hybrid zones. We identified over 1 million genetic variants between the parental species. Using pairwise SNP fixation index estimates between parental populations we identified genomic regions with exceptionally low and high differentiation among parental species. We further estimated the distribution of introgression across the genome by examining absolute pairwise divergence between the reference *A. palmata* genome and 20 additional *A. palamta* genomes across 50kb windows. Combined, these approaches elucidategeographic variation in genomic hotspots of introgression as well as barriers to hybridization with implications for how hybridization may shape adaptation in these important foundation species across the Caribbean and North-West Atlantic.

S10-6 KLEIST, NJ; GURALNICK, RP; CRUZ, A; LOWRY, CA; FRANCIS, CD*; Univ. of Colorado, Univ. of Florida, Cal Poly, San Luis Obispo; *cdfranci@calpoly.edu*

Anthropogenic noise, psychological stress and fitness: disrupted glucocorticoid signaling among breeding songbirds

Human-made noise is globally pervasive and degrades environments by disrupting organisms' abilities to interact with their environment acoustically. Although many species are now known to avoid noisy areas, data on whether those that remain in noise-polluted areas suffer physiological and fitness consequences are sparse. We used a unique study system in the natural gas fields of NW New Mexico, where anthropogenic noise is isolated from most variables associated with human activity, to understand how noise exposure influences stress physiology and reproductive success in three cavity-nesting birds. Across all species, we found noise to negatively influence baseline corticosterone concentrations in adults and nestlings and noise to positively effect stressor-induced corticosterone in nestlings. We also found noise to negatively effect fitness in two ways. In the noise-tolerant Western Bluebird elevated noise resulted in reduced hatching success. For all three species, nestling feather growth and body size showed a non-linear response to noise levels with accelerated growth in feathers and body size at intermediate noise levels. Our results are consistent with conservation concerns that noise exposure can negatively impact fitness. Additionally, our findings demonstrate that noise represents a chronic, inescapable stressor that causes glucocorticoid dysfunction in a manner consistent with responses to psychological stress in laboratory studies. Given that anthropogenic noise is ubiquitous, it is probable that many other species suffer similar physiological and reproductive consequences of noise exposure.

6-2 KLIMOVICH, CM*; WILLIAMS, SH; Ohio University; *ck841312@ohio.edu*

Investigations into the physiological and biomechanical basis of differential success in oral rabies vaccination between skunks (Mephitis mephitis) and raccoons (Procyon lotor)

Oral rabies vaccination (ORV) programs in North American have historically been effective in controlling the spread of rabies in raccoon, fox, and coyote populations. However, despite being a major rabies vector, the striped skunk is unresponsive to the vaccination programs utilizing oral rabies baits. Because they are responsive to the vaccine itself, solutions such as changing bait size or varying attractant scent have been proposed, but none have made a substantial effect when implemented. In this study, we explore biomechanical and physiological differences relating to biting, bait handling, oral processing and swallowing between skunks and raccoons that may contribute to differences in oral immunization success. The results of biomechanical models informed by jaw muscle and skeletal structure revealed that fiber architecture in skunks enables the production of high bite forces at large gapes. Bite force studies confirmed these results, with skunks biting just as hard as the raccoons at the same absolute gapes that match the size of the rabies baits utilized in ORV programs. Lastly, fluoroscopy studies revealed that skunk swallow speed may contribute to insufficient coverage of the lymphoid tissue for antibody production. This study represents the first time, to our knowledge, that comparative biomechanics have been used to address differences in vaccination program outcomes within and between species. With renewed interest in oral immunization as a safe, easily administered alternative to traditional vaccines, this study sets a precedent that will be useful to vaccine-bait developers.

86-2 KLITTICH, MR*; GARNER, AM; MAKSUTA, D; NIEWIAROWSKI, PH; DHINOJWALA, A; University of Akron; *mrk51@zips.uakron.edu*

Impact of Surface Chemistry on Gecko Self Cleaning

The gecko adhesive system continues to be an intriguing subject, particularly for biomimetics. Like geckos, mimetic adhesives should stick under non-ideal conditions, such as on partially contaminated surfaces. The gecko's glue-free hierarchical adhesive structure makes intimate contact with substrates, adhering with van der Waals forces. The presence of contaminants decreases adhesion, but geckos have been shown to self clean through stepping. The effectiveness of this self cleaning has been linked to an energy imbalance between the gecko, the contaminant, and the substrate. Due to the hydrophobic nature of the gecko's adhesive system, the energy balance can shift towards the particle remaining on the substrate, rather than on the gecko. This hydrophobicity stems from native lipids present on the surface of the *Gekko gecko*'s adhesive structure. Here, we have directly investigated the role of these lipids on the effectiveness of *Gekko gecko* self cleaning.

P2-244 KLOCK, A*; MACRANDER , J; REITZEL , AM; Univ. North Carolina Charlotte; *aklock@uncc.edu*

Toxin Expression and Effects on Predator and Prey in Two Model Sea Anemone Species

Cnidaria is the oldest venomous lineage in Metazoa and is characterized by the presence of stinging cells called nematocysts. These cells contain a number of toxin proteins that disrupt cellular homeostasis of predators and prey. Current research is lacking with regards to the venom expression or effect these proteins have on predator and prey. To elucidate the toxin activity and diversity within sea anemones, we used *Nematostella vectensis* and *Exaiptasia pallida* to characterize how specific toxin proteins interact with potential predators or prey. Sea anemones are bottom dwelling sessile predators with their mouth facing upwards surrounded by nematocysts packed tentacles. Of the two species, *N. vectensis* has the best characterized venom assemblage within sea anemones. The recent sequencing of *E. pallida's* genome allowed us to identify toxin candidates and speculate about their potential function. However, likely due to their evolutionary histories and differing environments, these species differ significantly in venom composition, which may play a major role in how they interact with potential predators or prey. In both species, we examined the difference in naturally induced toxin production in the oral region when anemones were exposed to a predator (*Palaemonetes pugio*) and prey (*Artemia salina*). We found that of the genes we examined most *N. vectensis* toxins had higher levels of expression when nematocysts were manually discharged, but had no change when exposed to predators or prey. *E. pallida* was found to exhibit a predatory response evidenced by increased expression in several toxin genes when exposed to water used to grow *A. salina*, indicating a physiological response to a potential food source. These results allow for future proteomics work to be completed on these model sea anemones as well as an insight into venom function based on associated biotic communities and their evolutionary history.

127-1 KLOMPMAKER, A.A.*; ROBINS, C.M.; FRAAIJE, R.H.B.; University of California, Berkeley, Oertijdmuseum; *adielklompmaker@gmail.com*

Parasitism in Crustaceans: Trends in Deep Time, Influence of Host Abundance, and Effect on Host Body Size

Despite the substantial impact of parasites on modern marine ecosystems, the evolution of parasitism in deep time is poorly known. The best-known record of parasites in fossil crustaceans are swellings attributed to isopods in the gill chambers of decapod crustaceans. This 180-million-year record allows us to (a) assess infestation patterns through time, (b) test whether the degree of infestation and specimen abundance per taxon are correlated, and (c) evaluate whether infested specimens are statistically smaller than non-parasitized conspecific specimens. We studied a variety of European decapod assemblages consisting of over 4000 specimens associated with Late Jurassic - Miocene sponge-coralgal habitats. Infestation percentages are highest in the Late Jurassic - Early Cretaceous interval (2.9 - 9.2%), while decapods with parasitic swellings are absent in the studied Late Cretaceous - Miocene assemblages. This decline may in part be explained by a drop in the abundance of commonly infested taxa such as homolodromioid brachyurans and galatheoid squat lobsters. The study of the two largest assemblages yielded mixed results regarding the influence of host abundance on the degree of infestation: a Late Jurassic assemblage shows no significant correlation, while an Early Cretaceous assemblage yields a positive correlation. Finally, infested specimens of two Late Jurassic species are significantly larger than conspecific specimens without a visible infestation, as opposed to studies on modern infested decapod species.

36-1 KNIGHT, K.C.*; LEE, D.V.; University of Nevada, Las Vegas; *kit.knight@unlv.edu*

Grasping lizard branch locomotion: an exploration of movement, forces, and torques

In many tetrapod groups, manual and pedal grasping is crucial for locomotion, reproduction, and acquisition of resources. Studies on locomotion of grasping arboreal lizards in terms of manual and pedal torques are absent from the literature. This study employs biplanar high speed videography and a custom designed, segmented, instrumented branch that can measure 3D forces and torques with resolution of 0.01 N and 0.001 N·m, respectively. Closely related pairs of lizard species from four major clades are being examined. In each pair, one species is primarily a ground dwelling lizard with some climbing ability and the other is a branch specialist lizard (BSL). A comparison of these lizards may help in answering the question of how reptile arboreal specialists move along a branch without falling. During locomotion along a branch, the center of mass (CoM) oscillates from left-right. If the CoM is not directly above the branch, the lizard must reposition the CoM above the branch, expend energy to hold the position, or fall. In this study, a few hypotheses are being tested: 1. BSL CoM forward velocity will be significantly slower during locomotion, 2. BSL will employ out-of-phase left-right tail movements to assist in repositioning the CoM above the branch, and 3. BSL will use grasping torques to assist in repositioning the CoM. The goal of this study is to shed light on the structure-function relationships of grasping appendages during branch locomotion in reptiles. This study may help further future work on understanding mechanisms for balance, control, and propulsion of tetrapods on narrow substrates.

P3-32 KNOWLTON, E*; GAFFIN, D; University of Oklahoma; *edkbiology@gmail.com*

Wolf Spider (Schizocosa avida) Vibratory Communication: Female Receptor Responses to Male Courtship

Spiders, and in particular, spiders of the genus *Schizocosa*, serve as model systems for exploring proximate and ultimate questions about the evolution of vibratory signals. However, little is known about the sensory response characteristics of receivers. We analyzed sensory structures on spider legs called metatarsal lyriform organs. Each lyriform organ contains aggregations of slit sensilla that respond to cuticular strain caused by substrate vibrations. At least two neurons innervate each sensillum. Here, we show how distal and proximal slit sensilla respond to male vibratory courtship components. We extracellularly recorded neurons within female *S. avida* legs as a male courted nearby. Distal slits respond primarily to male leg-tap vibrations while proximal slits respond to both male leg-taps and drumming of pedipalps (male appendages used for sperm transfer). Compared to control preparations in which female leg tarsi were immobilized preventing delivery of substrate vibration, treatment preparations of movable female tarsi yielded reliable neural responses to male courtship. Future work will continue probing the sensory processing features of females and explore how such receiver properties may influence the evolution of male signals.

14-3 KOCH, RW*; SHANNON, RP; GOEPPNER, S; BOLEK, MG; Oklahoma State University; *ryan.koch@okstate.edu*

Mysterious Snail Hosts: Distribution, Host Use, and Consequences of Acanthocephalans in Freshwater Snails

In many acanthocephalan life cycles, a vertebrate paratenic host is used to bridge the ecological gap between the intermediate and definitive hosts. However, there have been few reports of freshwater snails serving as paratenic hosts for acanthocephalans. To assess how commonly freshwater snails serve as hosts for acanthocephalans, two species of freshwater snails, *Helisoma trivolvis* and *Physa acuta*, were collected from various wetlands throughout Payne Co., Oklahoma. Additionally, snails were sampled on a monthly basis for a year from a single location to further investigate seasonal variation of infection. Acanthocephalans were identified to *Neoechinorhynchus* spp., which most likely infect turtle definitive hosts and ostracod intermediate hosts in nature. Depending on the site, prevalence and mean intensity ranged from 4-79% and 1-3.6, respectively. Throughout the year, prevalence and mean intensity peaked at 73% during the summer and decreased to 0% during the winter. We also measured snail egg production in the laboratory to examine differences between acanthocephalan-infected and uninfected field collected snails. Egg production did not differ significantly between infected and uninfected field collected snails. Finally, our histological analyses suggest there is an immunological response by the snail to the parasite, suggesting these acanthocephalans are metabolically active within their snail hosts. These results suggest that 1) location and season have a strong effect on the variation of acanthocephalan infections in snails; 2) acanthocephalans are using two different microhabitats within snail hosts; and 3) acanthocephalans appear to be growing and developing within snail hosts.

P1-37 KOCOT, K. M.*; TASSIA, M. G.; HALANYCH, K. M.; SWALLA, B. J.; University of Alabama, Auburn University, University of Washington; *kmkocot@ua.edu*

Phylogenomic resolution of major tunicate relationships

Tunicata, a diverse clade of over 3,000 species of marine, filter-feeding chordates, is the closest living relatives of vertebrates and thus is of great interest to researchers studying our own evolution and development. Despite their diversity and importance, relationships among major lineages of Tunicata are not completely understood. In order to improve understanding of tunicate phylogeny, we supplemented publicly available data with transcriptomes from seven additional species spanning the diversity of Tunicata and conducted phylogenomic analyses on data sets with up to 798 genes. We also conducted sensitivity analyses to examine the influence of reducing compositional heterogeneity and branch-length heterogeneity in our data. All analyses maximally supported a monophyletic Tunicata within Olfactores (Vertebrata + Tunicata). Within Tunicata, all analyses recovered the long-branched Larvacea sister to the rest of Tunicata and confirmed (with maximal support) that Thaliacea is nested within Ascidiacea. Stolidobranchia is the sister taxon to a clade in which Thaliacea is sister to Aplousobranchia + phlebobranch tunicates. Interestingly, in most maximum likelihood (ML) analyses, phlebobranchs were usually recovered paraphyletic with respect to Aplousobranchia. Support for this topology varied but was strong in some cases. However, BI analysis using the site heterogeneous CAT-GTR-Γ model recovered Phlebobranchia and Aplousobranchia reciprocally monophyletic with a posterior probability of 0.99, consistent with traditional morphology-based hypotheses. Examination of internode certainty also casts doubt on the ML result of phlebobranch paraphyly, which may be due to limited sampling for Aplousobranchia. Taken together, these results provide a higher-level phylogenetic framework for our closest living invertebrate relatives.

107-1 KOEHL, M.*; PEROTTI, E.; SISCHO, D.; HATA, T.; HADFIELD, M; Univ. of California, Berkeley, Univ. of Hawaii; *cnidaria@berkeley.edu*

Effects of Currents, Waves, and Biofilms on Motion of Tubeworm Larvae Swimming Above or Below Surfaces

Fouling communities on ships and docks develop as planktonic larvae of invertebrates settle onto them from flowing water. Competent larvae of the tubeworm *Hydroides elegans* settle and metamorphose only on biofilmed surfaces and are abundant early colonists in fouling communities. They were used to determine if the behavior of microscopic larvae carried in ambient water flow can affect their contacts with surfaces representing early stages of fouling community succession: clean flat surfaces, flat biofilm, or biofilm on rough worm tubes. Most flume studies of larval settlement are done in unidirectional flow along a floor, but we videotaped the motion of larvae near both ceiling and floor of a small flume in which we mimicked fine-scale flow measured near surfaces in a harbor: unidirectional current or small waves superimposed on a current. In flowing water near surfaces, larval motions can be due to active behavior and passive transport. Live larvae moved up and down across the boundary layer more than passive dead larvae, and a higher percent of live larvae contacted surfaces. Live larvae "bounced" along a surface after landing while dead larvae did not, so live larvae touched a surface more times per distance they were carried by the flow. Contacts by live larvae on clean surfaces were shorter than on biofilm, but did not differ between flat and rough biofilmed surfaces. Touch durations of live larvae on biofilm were shorter in flow than in still water, but adding small waves to a current did not affect larval contacts. Similar patterns occurred for ceiling and floor. Thus, active behavior of larvae swept past surfaces by flow can affect how they contact those surfaces.

103-1 KOENIG, KM; Harvard University; *kmkoenig@fas.harvard.edu*

Early Eye Development in the Squid Doryteuthis pealeii and the Evolution of Morphogenesis

Classically, the cephalopod eye is known for its morphological similarity to the vertebrate single-chambered eye. However, this complexity is independently evolved. While vertebrate and fly eye and organ formation have been well studied, little is understood about the coordinated cellular movements that generate complex structures outside of traditional models, like the cephalopod eye. Our interest is to better understand the morphogenesis of complex visual systems in a comparative manner with the goal of revealing basic cellular mechanisms involved in elaborating simple organs into more complicated morphologies. The single-chambered eye of the squid *Doryteuthis pealeii* is an ideal system to study these processes because eye formation occurs on the exterior of the embryo and is easily visualized. Early in development, the cephalopod eye forms through the internalization of two bilateral retinal placodes by the future lens and iris tissue. This internalization event generates the optic vesicles. These vesicles will eventually grow and develop to generate all the cell types that compose the eye. We have developed in vivo imaging protocols using long-term light-sheet microscopy to better understand tissue movements and cell behaviors during this internalization event. These data highlight how this morphogenetic process differs from other examples of "hole closure" such as *Drosophila* dorsal closure, wound healing and eyelid closure in mouse. Together this work reveals new insights into epithelial morphogenesis and the generation of complexity found across the Bilateria, and supports the need for broader study of these types of collective cellular mechanisms across the tree.

140-7 KOESTER, JA*; HELLIWELL, KE; TAYLOR, AR; University of North Carolina Wilmington, Marine Biological Association, Plymouth, UK; *koesterj@uncw.edu*

Characterization of Na^+ channel homologs from two marine phytoplankton

Four domain voltage-gated Na^+ and Ca^{2+} channels mediate rapid physiological responses in metazoans. Fast Na^+ and Ca^{2+}-based action potentials likely evolved in single celled organisms before the evolution of multicellular neuromuscular systems, although their functional role is not well understood. We recently discovered that fast action potentials in some marine phytoplankton may be underpinned by homologs of single domain bacterial Na^+ channels (NavBac), suggesting a unique role of these proteins in unicellular eukaryotes. We therefore heterologously expressed two NavBac homologs, one from the diatom *Odontella sinsensis* and one from the coccolithophore *Scyphosphaera apsteinii* in the mammalian cell line HEK293. Whole cell patch clamp analysis revealed that the expressed proteins from both species mediate fast activating, rapidly inactivating inward currents in response to depolarization. Both channels exhibited steady state inactivation with recovery from inactivation. The coccolithophore protein exhibited much faster activation and inactivation kinetics (τ_{act}=0.62 ms ± 0.40, τ_{inact}=1.16ms ± 0.34) compared to the diatom protein (τ_{act}=1.18 ms ± 0.53, τ_{inact}=46.90ms ± 8.50). These kinetic features are similar to the properties of four-domain voltage-gated Na^+ channels in animals, implying the single-domain proteins tetramerize to form a functional voltage gated channel. Differentiation in the amino acids of the selectivity filter suggests that the coccolithophore channel selects for Na^+ over Ca^{2+}, while the diatom channel is permeant to Ca^{2+}. Our data suggest unique functional roles for single-domain voltage-gated Na^+ and Ca^{2+} channels among the diverse lineages of marine protists.

4-3 KOHL, K.D.*; BRUN, A.; CAVIEDES-VIDAL, E.; KARASOV, W.H.; Univ. of Pittsburgh, Univ. of Wisconsin - Madison, Universidad Nacional de San Luis; *kevin.d.kohl@gmail.com*

Gut microbial ecology of nestling House Sparrows (Passer domesticus)

Recently, there has been a great deal of attention focused on the role that symbiotic bacteria play in the development, ecology, and evolution of hosts. Avian altricial nestlings represent an interesting study system in which to investigate these interactions, given that they exhibit the fastest growth rates among vertebrates, and growth is limited by their digestive capacity. We used 16S rRNA sequencing to inventory microbial communities in several experiments testing various questions. 1) How do microbial communities develop in the wild? 2) How responsive are gut microbes to dietary changes? 3) Does hosting microbes incur a cost to developing nestlings? When sampling nestlings from the wild, we found that aspects of bacterial community membership and structure changed significantly over the nestling period. The relative abundance of Proteobacteria decreased around day 9, while the relative abundance of Firmicutes increased. When we conducted feeding trials in captivity, we found that the microbial communities were altered within 6 hours of a diet shift. Last, we treated some nestlings with antibiotics. Antibiotic treatment significantly increased growth and food conversion efficiency in nestlings. Antibiotics did not alter aspects of gut anatomy, but depressed intestinal maltase activity. Thus, we conclude that microbial-induced growth limitation in developing birds is not driven by interactions with digestive capacity, but may be driven by decreased energetic costs of immune function or beneficial effects from microbes enriched under antibiotic treatment. Overall, these studies demonstrate that the digestive system and gut microbiota of developing House Sparrows respond rapidly to changes in diet.

P1-229 KOHL, K.D.*; FONTAINE, S.; NOVARRO, A.J.; Univ. of Pittsburgh, Univ. of Maryland; *kevin.d.kohl@gmail.com*

Environmental temperature alters the gut microbiota of the eastern red-backed salamander (Plethodon cinereus)

There has been recent interest in the role that host-associated microbes play in the ecology and evolution of animal hosts. However, many environmental factors can influence these relationships. Here, we investigated the gut microbial community structure of salamanders held at 10°C, 15°C, and 20°C. Fecal samples were collected to inventory the gut microbial communities by sequencing the 16S rRNA gene. Also, food intake and production of feces were used to calculate assimilation efficiency. Temperature significantly changed gut microbial community membership and structure. Salamanders held at 20°C had lower microbial diversity compared to those at 10°C or 15°C, as measured by Shannon index, Faith's phylogenetic diversity, observed number of microbial taxa, and evenness. Salamanders at higher temperatures had higher relative abundances of the bacterial phylum Bacteroidetes and lower abundances of Actinobacteria. We will also investigate for correlations between relative abundances of microbial taxa and measured whole-animal assimilation efficiencies. Our results highlight that environmental temperatures may influence the function of host-associated microbial communities.

P1-144 KOHLRUSS-REUMAN, PS*; GAMBOA, MP; GHALAMBOR, CK; Colorado State University; *phalenkr@colostate.edu*

Birds of a Feather: The Effects of Climate Variation on Feather Morphology

Strong divergent selection and limited gene flow across varying environments should lead to adaptive population differentiation. Archipelagos are unique evolutionary models to understand the role of divergent selection on phenotypic differences given the relative isolation of island populations. On the California Channel Islands, song sparrows (*Melospiza melodia graminea*) are found along a strong climate gradient and exhibit low dispersal across islands. Divergent selection due to climate has been linked to variation in bill size, a tool used to radiate heat. However, the bill represents only a small proportion of a bird's surface area that can lose heat, and denser plumage may be an effective means of reducing heat dissipation in cooler environments. Here, we test the relationship between climate and feather micro-structure. Specifically, we looked at breast contour feathers from birds on islands representing different climates and compared characteristics of the plumulaceous and pennaceous sections—the plumulaceous section being most closely associated with insulation ability. We find significant differences between islands in the proportion of the feather that is plumulaceous, as well as evidence for greater barb density in birds from colder islands. Both higher barb density and a higher proportion of plumulaceous feather area provide better insulation, and this suggests selection due to climate differences may facilitate these population differences.

44-5 KOLMANN, MA*; HUIE, J; EVANS, K; SUMMERS, AP; University of Washington, University of Minnesota; *kolmann@uw.edu*

View to a keel: aggression, armor, and scale-feeding in piranhas

Intraspecific aggression has led to some of the most extravagant examples of animal display, weaponry, and ornamentation; used for awing admirers, intimidating rivals, or injuring would-be assailants. This is especially clear in the Neotropics, where in freshwater habitats, high species richness leads to all manner of animal ornamentation and display. For example, catfishes use venomous spines to deter predators, garishly-colored cichlids display to favored females and rival males, while drab knifefishes 'catcall' with electric signals. Other fishes scrap it out more directly; piranhas and other serrasalmids defend their nests and foraging territories from conspecifics and confamilials alike, regularly chasing and biting each other. We surveyed serrasalmid morphology with micro-computed tomography, and discovered that piranhas have a high prevalence of skeletal injury. Damage was particularly common on the bony, armored keel, which we propose defends against conspecific aggression. Piranha schools may also face aggression from confamilial parasites in sheep's clothing: scale-feeding wimple piranhas. We examine the ontogeny of feeding morphology in *Catoprion mento*, one of the few piranhas which scale-feed through to adulthood. Few characters distinguish *Catoprion* from piranhas which scale-feed solely as juveniles, suggesting it retains some paedomorphic characters to adulthood. The robust teeth and elongate lower jaw in this taxon are critical to scale-feeding performance, leveraging scales and mucus from prey. Overall however, the unspecialized nature of the feeding apparatus in *Catoprion* suggest that transitions to (or away) from scale-feeding are mediated by small changes in developmental timing.

6-4 KONOW, N*; SOLOMON, J; HEISS, E; WITZMANN, F; GIUFFRIDA, E; UMass Lowell, Friedrich Schiller University, Museum fur Naturkunde; *nicolai_konow@uml.edu*

Integration of Hyoid Protractor and Retractor Muscle Action in Tongue Control of Food during Axolotl Chewing

Aquatic feeding vertebrates must balance risks of food escape with requirements for food processing before swallowing. Food control in water depends on the tongue (hyoid) acting as a hydrodynamic piston to produce fine-scale intraoral water flows and control food positioning before a processing power stroke is initiated. However, the deep, hidden placement of the musculoskeletal elements involved has challenged measurements of tongue and food movements during feeding. We used biplanar fluoroscopy to record skeletal movements (XROMM), muscle strains, and food movements (fluoromicrometry) during chewing in Axolotls. We tested an idea arising from prior EMG studies; that muscle-driven motion of the tongue moves food caudally during gape opening, likely to prevent its escape. During gape opening, in preparation for the power stroke, we measured shortening of the hyoid retractor in the majority of cycles, resulting in caudoventral hyoid and food excursion. However, other cycles involved lengthening of sternohyoid, or alternatively shortening of both the hyoid pro- and retractor, resulting in elevation and/or rostrad excursion of the hyoid during, and even prior to gape opening. Whereas contractions of the hyoid pro- and retractor are tightly integrated and coordinated, consistent with the idea that the tongue moves water to exert food displacement, there is considerable temporal variation in hyoid movement with respect to jaw muscle action and jaw cycle. These results underscore problems associated with predicting hidden motion based on EMG, suggest the presence of elastic elements within the hyoid musculature, and document an unappreciated diversity in salamander chewing function.

P3-18 KOO, AI*; PETERSEN, C; HURLEY, L; Vassar College, Indiana University, Bloomington; *alkoo@vassar.edu*

Localizing the source of context-dependent serotonin release in the inferior colliculus.

Behavioral and physiological context is essential to sensory processing. The neuromodulator serotonin (5-HT) within the inferior colliculus (IC) has been shown to modulate depending on the context. Most 5-HT in the IC is provided by the dorsal raphe nucleus (DRN), but no studies have looked at which DRN subregions have 5-HT projections to the IC. We therefore sought to localize the source of 5-HT in the IC within the DRN. Male CBA/J mice (n=6) received stereotaxic injections of Retrobeads, a retrograde tracer, into the IC. Five days post-op, mice were sacrificed and their brains were extracted and sliced. Sections were then labeled for tryptophan hydroxylase (TPH) via immunohistochemistry, and double-labeled cells in each DRN subregion were counted. We localized most double-labelled cells to the dorsal subregions of the mid-rostrocaudal DRN. The rostral and caudal DRN contained relatively few neurons backfilled with Retrobeads. The results suggest that the dorsal subregions of the mid-rostrocaudal DRN may play a role in processing context-specific auditory cues. To give functional support to our anatomical findings, we next examined whether the serotonergic DRN to IC projections are active during exposure to contexts that have previously been shown to modulate 5-HT levels within the IC. Mice (n=12) received stereotaxic injections of Retrobeads and were exposed to stressful, social, or control environments. Five days post-op, brains were extracted, sectioned, and labeled for TPH and c-fos via immunohistochemistry. Triple-labelled neurons were then counted. We are still counting cells, but we expect to find more serotonergic back-filled neurons in the dorsal subregions of the mid-rostrocaudal DRN to be active during the stressful and social contexts relative to the control group.

P1-137 KOSTECKA, L.G.*; WORTHAM, J.L.; University of Tampa; *laurie.kostecka@spartans.ut.edu*

Morphology of the Grooming Appendage in Smasher and Spearer Mantis Shrimps

Grooming behaviors decrease fouling on body regions and these behaviors can be efficient in keeping respiratory and sensory structures functional. Within one group, such as decapod crustaceans, appendages and morphologies of these grooming appendages are different. Setae on grooming appendages are important in removing fouling and increasing sensory reception. Mantis shrimp are marine crustaceans divided into two groups based on the morphology of their feeding raptorial appendage. Generally, "spearers" have a knife-like appendage, usually live in deeper waters, and are nocturnal while "smashers" have a club-like appendage, usually live in shallow waters, and are active in the daytime. These groups have different grooming time budgets and body regions groomed, but both groups only have one grooming appendage, the first maxilliped. The objective of this research was to describe the morphologies of this grooming appendage in both mantis shrimp groups and to document similarities and/or differences in the setal types and structures on this grooming appendage. Because smashers groom more often and for more time compared to spearers, smashers were predicted to have less elaborate setal morphologies (hence why they groom more than spearers). The first maxilliped of smasher and spearer species (N=2 and N=2, respectively) were observed using microscopy. Overall, most morphologies of the groups were similar, with some minor differences in setal types and their locations on the appendage. The setae found on the grooming appendages were serrate setae, layered "rasp" setae, multiscaled setae, and comb serrate setae. In terms of number of setae associated with the grooming appendages, both mantis shrimp had equal number of setae on grooming appendages but the density of setae did vary.

P3-248 KOVACS, JL*; GAILLARD, E; Spelman College, University of North Carolina; *jkovacs@spelman.edu*

Investigating the effects of urbanization on bird biodiversity: Testing three biodiversity hypotheses using citizen science data

Urbanization can affect biodiversity in a variety of ways, including habitat loss and fragmentation and the introduction of non-native species. While we predict that human disturbance should impact the distribution and abundance of species in urban areas, what the actual relationship between urbanization and biodiversity is often unclear and may vary between plant and animal groups and even within groups of species. There are three main hypotheses that predict how urbanization should impact overall biodiversity in impacted habitats. The productivity hypothesis predicts that the increased resources available in urban environments will result in an increase in biodiversity. The ecosystem stress hypothesis predicts a decrease in biodiversity in urbanized areas due to the stress associated with living in an altered habitat. The intermediate disturbance hypothesis predicts that areas that are moderately disturbed/ urbanized should have the highest diversity compared to highly urbanized or undisturbed habitats. We tested these predictions using publicly available bird biodiversity data collected by the citizen science program eBird (Cornell Ornithology Lab). We have calculated bird biodiversity measurements for multiple locations in Florida and Alabama spanning a 10 year period. We then calculated changes in land use and urbanization using land use data (LandSat and QGIS) in those same locations over the same 10 year period.

P1-49 KOYAMA, KH; ARENZ, AL*; RIVERA, AS; University of the Pacific; *a_arenz@pacific.edu*

Euphilomedes as a model system for studying ostracod evolution and development

Ostracods are a compelling clade for evolutionary and developmental biology studies as they are basally branching crustaceans. Crustaceans in general display a wide-variety of developmental strategies and are morphologically diverse. However, the evolution of many compelling crustacean features - such as diverse limbs and sensory systems - are not well understood due to a lack of sampling across clades. We are currently using *Euphilomedes* (Myodocopida; Sarsielloidea; Philomedidae) as a novel model for studying evolution and development within Ostracoda. Some species of *Euphilomedes* are easy to collect and maintain in the lab through all stages of development, transcriptomes have been sequenced from two species, and they exhibit the compelling feature of highly dimorphic eye morphology. We focus here on three major research programs in our lab: 1) Early cell division and migration patterns 2) Gene expression differences underlying sexually dimorphic eye types 3) Ecological factors driving the evolution of sexually dimorphic eyes.

13-5 KOZMA, MT*; SCHMIDT, M; SPARKS, SD; NGO-VU, H; SENATORE, A; DERBY, CD; Georgia State Univ., Univ. of Toronto Mississauga; *mtottempudi1@student.gsu.edu*

Expression of variant IRs, GRs and TRP channels in chemosensory organs of Caribbean spiny lobster, Panulirus argus.

The spiny lobster, *P. argus*, has two classes of chemosensilla representing "olfaction" and "distributed chemoreception." Olfactory sensilla are found exclusively on antennular lateral flagella (LF) and are innervated only by olfactory receptor neurons (ORNs) that project into olfactory lobes organized into glomeruli. Distributed chemoreceptor sensilla are found on all body surfaces including LF and leg dactyls, and are innervated by both chemoreceptor (CRNs) and mechanoreceptor neurons that project into somatotopically organized neuropils. Here, we examined the expression of three classes of chemosensory proteins in transcriptomes of the olfactory organ (LF), distributed chemoreception organ (dactyls), and brain of *P. argus*: Ionotropic Receptors (IRs), which are related to ionotropic glutamate receptors and found in all protostomes including crustaceans; Gustatory Receptors (GRs), which are ionotropic receptors that are abundantly expressed in insects but are more restricted in crustaceans; and Transient Receptor Potential (TRP) channels, a diverse set of sensor-channels that include several families of chemosensors in diverse animals. We identified over 100 IRs, 1 GR, and homologues for most Group 1 TRP channel subfamilies. The number of IRs expressed in the LF is far greater compared to the dactyls. We found co-receptor IRs, IR25a, IR8a, IR76b, and IR93a, and conserved IR, IR40a, in all three tissues. Immunocytochemistry showed that IR25a is expressed in most ORNs, CRNs, and specific cells near the olfactory lobe. While the function of these receptors was not explored, our results suggest an abundant diversity of chemoreceptor proteins. Further analysis will explore the expression of these proteins in additional decapod crustacean species.

P1-215 KRAJNIAK, KG*; YOUNGBLOOD, M; MUETH, L; KRISHNAKUMAR, A; Southern Illinois University Edwardsville; *kkrajni@siue.edu*

The effects of several pentapeptides related to FMRFamide on the isolated crop-gizzard of the earthworm, Lumbricus terrestris.

A wide variety of FMRFamide-related peptides (FaRPs) have been isolated from or predicted in the genomes of annelids. N-terminally extended peptides with the C-terminal sequence YVRFamide have been predicted in the classes Polychaeta and Clitellata. Prior experiments using the isolated crop-gizzard of the earthworm, *Lumbricus terrestris*, showed that polychaete AGAYVRFamide was excitatory, while clitellate APKQYVRFamide and PAKHYVRFamide were inhibitory on the contraction amplitude. In the same experiments we found YVRFamide, the tetrapeptide core in all three peptides, was excitatory. In this study we used AYVRFamide, QYVRFamide, and HYVRFamide on the isolated crop-gizzard to determine whether the additional amino acid on the N-terminal caused a response similar to the full peptide sequence or YVRFamide. The crop-gizzard was removed from the animal, placed in a tissue bath filled with earthworm saline, and attached to a force transducer which was connected to a computer using Iworx software to record the contractions. Increasing concentrations of peptide were injected into the tissue bath and the resulting changes in contraction rate and amplitude were used to create log-concentration response curves. Both AYVRFamide and QYVRFamide caused a decrease in amplitude with a threshold between 1 to 10 nM. HYVRFamide caused a biphasic change in amplitude with a decrease in amplitude at 1 nM and an increase in amplitude at 1 µM. Thus the addition of the next amino acid on the N-terminal of YVRFamide did not always restore the activity observed with the full peptide sequence. This suggests that the crop-gizzard receptor requires a more complete sequence than five amino acids to restore the response. In the future we will examine the effects of adding back another amino acid to the N-terminal.

120-4 KRASKURA, K*; NELSON, J; Univ. of California, Santa Barbara, Towson University; *krista.kraskura@lifesci.ucsb.edu*

Fitness components of individual fish that experience hypoxic dead zones under normoxia and hypoxia

Hypoxia in Chesapeake Bay from anthropogenic activities is a major concern. For obligate aerobes like juvenile striped bass, incursion into these increasingly prevalent hypoxic zones creates additional metabolic pressure when performing energetically expensive activities such as swimming. When in these hypoxic waters, the Darwinian fitness of these fish may depend on their tolerance of hypoxia (HT) and/or ability to escape the hypoxic region by swimming away from it. Here we measured the relative HT of 18 juvenile striped bass twice, 11 weeks apart, and their oxygen consumption rate while swimming in low flow (10.2 cm s^{-1}) and high flow (estimated 67 % U_{max}) under normoxia (>90% air saturation, AS) and hypoxia (20% AS). The rank order of individual HT was significantly repeatable over the 11-week period, and HT increased significantly in most individuals. Oxygen consumption was lower while swimming against low flow regardless of available oxygen levels, but was significantly lower in hypoxic water under high flow. There were no clear relationships or trade-offs between an individual's relative HT and their oxygen consumption while swimming under any conditions. Only an individual's increase in HT after multiple hypoxia exposures and oxygen consumption rate in low flow were significantly-negatively correlated. Importantly, both HT and oxygen consumption rate were repeatable and varied substantially among individuals suggesting that they may be targets of natural selection in fish occupying hypoxia-prone waters

P3-102 KRAUSE, JS*; REID, AMA; PEREZ, JH; BISHOP, V; CHEAH, JC; WINGFIELD, JC; MEDDLE, SL; KRAUSE, Jesse; Univ. of California, Davis, Roslin Institute, Univ. of Edinburgh; *jskrause@ucdavis.edu*

Hepatic corticosterone binding globulin (CBG) mRNA expression across life history stages in migratory and nonmigratory subspecies of White-crowned sparrow

Corticosterone binding globulin (CBG) is the major transport protein for both corticosterone and testosterone steroids in birds and is primarily produced in the liver. Binding assays for CBG along with immunoassays for corticosterone, the stress hormone, indicate that both analytes can vary by life history stage and often peak during breeding. Additionally, harsh conditions are known to stimulate the hypothalamic-pituitary-adrenal (HPA) stress axis. We investigated how life history stage and environmental conditions influenced hepatic CBG mRNA expression in migratory and non-migratory subspecies of White-crowned sparrow (*Zonotrichia leucophrys*). We predicted that harsh conditions would promote CBG expression to aid steroid transport in the blood stream. Birds were sampled during breeding, molt and wintering life history stages. CBG was upregulated in male migrant sparrows compared to non-migratory residents during the breeding stage only. Migrants exhibited peak CBG expression during breeding while no other seasonal differences were detected for either subspecies regardless of sex. Our results suggest that CBG expression is affected by seasonal stage in migratory White-crowned sparrows only, possibly due to harsher environmental conditions experienced at breeding sites.

44-2 KRENTZEL, D*; ANGIELCZYK, K; Univ. of Chicago, Field Museum; *dkrentzel@uchicago.edu*

The elegance of ever-growing incisors: biomechanics and ecomorphology of unique rodent dentition and musculature as the drivers of diversification

Rodents comprise the majority of mammal species and present the widest array of diets, but their incisors appear simple and conservative. We argue that the ever-growing incisors of rodents are an elegant tool for manipulating their environment, driving their diversification. These teeth are unique among mammals due to their specialized self-sharpening adaptations and functional decoupling of gnawing from chewing. Here we assess the relationship between incisor shape and diet/function across a representative sample of 271 rodent genera spanning each masseteric configuration in order describe how incisor shape is adapted for specialized and generalized masticatory functions. Our results demonstrate that incisor size and shape are unrelated to cheekteeth size and shape across rodent phylogeny, corroborating the hypothesized independent functional utilization of these modules within the feeding system in rodents. We find that rodent lineages lacking a myomorphic masseteric configuration (in which there are two specialized anterior masseter units instead of one) are often specialized in diet and exhibit incisors with unique morphologies for vegetative cropping, digging, and hard nut/seed feeding. Myomorphic rodents, despite their wide diversity of diets and high diversification rates, demonstrate more conservative incisal morphologies. We argue that the simplicity of ever-growing incisors has allowed rodents to achieve the most extreme ecomorphological versatility in mammals, and that myomorphic species in particular exhibit even further dietary lability without the same diversity of incisor shapes thanks to the synergistic interaction between their derived anterior masseteric units during gnawing.

P2-27 KRIEGER, D*; ROBERTS, S; PERCH, University of Pennsylvania, Electrical and Systems Engineering, University of Pennsylvania; *diedrak@seas.upenn.edu*

Using the art practice of play to communicate legged robotics research concepts

The art practice of play uses spontaneity and surprise to communicate meaningful content and inspire critical thinking (1-3). We describe three engineering education outreach efforts that use play to communicate legged robotics research concepts. In the first workshop, Penn engineering students were motivated to learn how to program a legged robot using the narrative of a "dance competition," with the winning dances to be showcased at the Philadelphia Science Festival. In the second workshop, Philadelphia School District high school students used a poseably programmable legged robot to tell a story by performing a series of behaviors in a set of their own design and documenting the story as a video artwork. Here, there were two narratives: One created by the workshop directors, communicating concepts about complex multi-legged behaviors and gaits, and the other created by the students using the robots to express their ideas. In the final workshop, middle school students created locomoting robots using motors, post-consumer materials, and basic art supplies. The concepts of energy and physical programming were demonstrated using working Trashbots and practiced during an introductory exercise making a vibrating motor from a spinning one. Participants then created a robot of their own design using iterative experimentation. We conclude from these three workshops that play can be used as a vehicle for scientific communication. (1) David Getsy, ed. *From diversion to subversion: Games, play, and twentieth-century art, Vol. 16* (Penn State Press, 2011). (2) Nato Thompson and Gregory Scholette, eds. *The interventionists: Users' manual for the creative disruption of everyday life* (MIT Press, 2004). (3) Diedra Krieger, 'Plastic Fantastic,' Gyre Exhibition, Anchorage Museum, Alaska, 2014.

P3-34 KROTINGER, AK*; PERKS, KE; BODZNICK, D; Wesleyan University, Marine Biological Laboratory, Columbia University; *akrotinger@wesleyan.edu*

Adaptive Sensory Filtering in the Hindbrain Mechanosense Nucleus ofLeucoraja erinacea

Sensory self-stimulation from an animal's own behavior often produces stronger signals than important stimuli in its environment, yet the brain filters out these self-generated signals. We have previously shown that the principal neurons in the primary electrosensory nucleus of the skate (*Leucoraja erinacea*) learn to recognize and reject sensory signals consistently associated with the animal's own behavior or the motor commands for behavior recorded in a paralyzed fish. This adaptive filter mechanism is mediated by a distinctive anatomical organization and molecular layer that is also characteristic of the cerebellum. The same organization is found in the medial nucleus, which processes incoming mechanosensory lateral line information. This similarity suggests the medial nucleus may contain the same adaptive filter mechanism to filter out mechanosensory self-stimulation. Previous work of Perks (2007) demonstrates the presence of adaptive filtering in the lateral line when an external mechanosensory stimulus is consistently linked with ventilation or fictive ventilation. Here we provide additional support for Perks' findings, as well as results indicating adaptive filtering in cells that were tested by associating a stimulus with fictive swimming, another distinct behavior. For these experiments we coupled an external mechanosensory stimulus to each cycle of the skate's fictive swimming as indicated by motor discharges recorded from the spinal cord. These results showing the presence of the adaptive filter in yet another sensory system help piece together a model of how the cerebellum integrates, processes, and predicts sensory consequences of behavior.

61-6 KUAN, K-C; SHIH, M-C; CHIU, C-I; CHI, K-J*; LI, H-F; National Chung-Hsing University, Taiwan; *kjchi@phys.nchu.edu.tw*

Fast Strike of Twisted Mandible in Termite Soldiers of Pericapritermes nitobei

The soldiers in different termite species, all considered eusocial, have evolved diverse defense mechanisms for enemy or predators; for those inhabit in soil, elastic snapping mandibles are observed in several termite genera. Previous study reported that the symmetric mandibles of *Termes panamaensis* soldiers could render a snapping speed of 67 m/s, ranked as top record with trap-jaw ants among bio-movements. In this study, we examined the snapping mechanics of twisted left mandibles in *Pericapritermes nitobei* soldiers to test previous hypothesis that such presumably derived asymmetric form could perform more violent strike due to greater elastic energy stored in single mandible. Without sufficient equipment to directly film the mandible snapping behavior, we set up ball-strike experiments, filmed at 1000 fps, and conservatively estimated the striking (snapping) speed using the law of conservation of energy. The ball was mostly hit when the deformed left mandible returned to its original position where all the stored elastic energy transformed into kinetic energy. The estimated snapping speed had a mean of 55 ± 21 m/s ($n = 6$); half of the subjects could snap faster than 80 m/s and the maximum was 97 m/s. A recent filming trial at 460 kfps yielded result of 130 m/s, which sets the new record in bio-movements and proves our method a feasible and credible alternative for fast motion analysis. Comparison of mandible snapping mechanics not only allows us to examine termite soldier's defensive strategy and their ecological-evolutionary consequences, but also provides insights to bio-inspired elastic structures and strong materials.

P3-165 KUEHN, AL*; MAIN, RP; LEE, AH; SIMONS, ELR; Midwestern Univ., Purdue Univ.; *esimon@midwestern.edu*

The Effect of Growth Rate and Biomechanical Loading on Bone Laminarity in the Emu Skeleton

The orientation of vascular canals in primary bone may reflect differences in growth rate and/or adaptation to biomechanical loads. Circularly-oriented canals (forming laminar bone) are hypothesized to reflect rapid growth rate or locomotion-induced torsional loading. The femur and tibiotarsus (tbt) of emu experience large shear strains (torsional loads) during locomotion that increase through ontogeny. Emu wings are very reduced and minimally loaded. Here, we test how growth rate and biomechanical loading affect bone laminarity in 5 elements (femur, tbt, humerus, ulna, and radius) from growing emu (2-60 wks). If laminarity reflects rapid growth rate, it should be most elevated at the growth spurt in all elements. If laminarity reflects biomechanical loading, it should increase with shear strains and be most abundant in the adult in hindlimbs only. Xylenol orange and calcein were injected into growing emu to fluorescently tag periosteal growth fronts. Transverse mid-shaft sections were prepared and imaged. To calculate daily growth rate, we divided the distance between fluorescent tags by days between injections. The proportion of circularly oriented canals (laminarity index) was measured. Overall, the growth rate exhibits a bell-shaped distribution with age with the growth spurt occurring at 5 wks. Bone laminarity decreases with increased growth rate in all elements. A positive relationship between laminarity and shear strain in the femur and tbt suggests that elevated laminarity is related to the relatively larger torsional loads placed on the hindlimb elements as the bird increases in age/mass. In conclusion, biomechanical loads seem to play a dominant role in the development of bone microstructure in the emu hindlimb.

P1-283 KUHN-HENDRICKS, SM*; ERICKSON, GM; Florida State University; *sh12f@my.fsu.edu*

A Novel, Phylogenetically-Informed Approach for Investigating Material Properties in Biological Hard Materials with Implications for Biomimetic Ceramic Designs

Biological hard materials show considerable promise for inspiring next generation high-performance ceramics and composites. Complex architectures in materials such as nacre and tooth enamel display high mineral volume fractions, yet possess exceptional fracture resistance instead of brittle behavior. Previous research has evaluated material properties of such tissues in only one or a few taxa, with little consideration of their phylogenetic history. Here, I develop a novel evolutionary framework for evaluating the material properties of hard biological materials and employ it to identify adaptation in response to new loading scenarios and mechanical demands. As a case study, changes in material response of complex enamel microstructures in mammalian dental enamel are investigated across two classic vertebrate dietary transitions: the evolution of 1) grazing in equid ungulates; and 2) durophagy in hyenids. Berkovitch nanoindentation and Vicker's microindentation are used to measure enamel elastic modulus and hardness in living and fossil ingroup and outgroup taxa. A new method is created for quantifying preferred fracture propagation orientation within the tissues. In contrast to isotropic fracture in ancestral radial enamel, modified radial enamel in advanced equid genera channels fractures along interprismatic rows, inhibiting enamel spalling on enamel crests. Fracture response in hyenid zig-zag Hunter-Schreger bands (HSB) is complex, with crack arrest at HSB boundaries preserving whole tooth function; ancestral radial enamel does not contain structures for crack arrest. However, elastic modulus and hardness are similar across microstructures. Using this approach, microstructural adaptation can be linked to material response, providing new avenues for materials development.

P3-141 KUMAR, J; MALIK, S; BHARDWAJ, SK; RANI, S*; UNIV. OF LUCKNOW, LUCKNOW, UNIV OF LUCKNOW, LUCKNOW, CCS UNIV. MEERUT; *sangeetarani7@yahoo.com*

Night light alters the perception of day length in migratory redheaded bunting: implications for avian migrant conservation

Study on ecological consequences of night-light (NL) has received great interest in last decade. The pattern of NL may vary with the geographical region and its night-life. It may be available as high intensity light throughout night or in short durations breaking the night into ‘part night' which could be critical for a nocturnal migrant in timing its migration and reproduction. We tested this in controlled laboratory environment by exposing the migratory redheaded bunting (Emberiza bruniceps), a long distance Palaearctic-Indian migrant overwintering in India, to NL at different phases of night. Winter daylengths are not stimulatory for buntings but increasing daylengths of spring prepare them for vernal migration and subsequent reproduction. Four groups of male buntings captured from overwintering flock were transferred to individual activity cages and maintained under non-stimulatory short days (8L:16D; L = 100lux, D = 0.1lux) for 2 weeks. Later, they were given urban night-light (NL) environment (~2lux light intensity) for 4hours (4h) in continuation with onset of night (early night; ZT 08-12; group 1, ZT0= zeitgeber time 0, time of lights on), at mid-night (ZT 14-18; group 2) or preceding the day's onset (ZT 20-24; group 3), or for 16h (ZT 08-24; group 4) throughout night. Birds in all groups showed intense nighttime activity, altered melatonin and temperature rhythms, increase in body mass and body fattening, food intake and gonadal size in otherwise non-stimulatory daylengths suggesting that NL changes the perception of daylengths longer than they actually are. This information may be valuable in adopting part-night lighting approach to help reduce the physiological burden such as early migration and reproduction, of artificial lighting on the nocturnal migrants.

P1-115 KUMLER, W.E.*; KOEHL, M.A.R.; Univ. of California, Berkeley; *wkumler@berkeley.edu*

Evolution of multicellularity: Capture of unicellular vs colonial choanoflagellates by a passive protozoan predator

Choanoflagellates are protozoans that can be unicellular or can form multicellular colonies. Because genomic and molecular phylogenetic analyses indicate that animals and choanoflagellates shared a common ancestor, choanoflagellates are used as model organisms to study the evolution of multicellularity. It has been proposed that avoidance of predation by other protozoans might have been an important selective factor favoring the evolution of multicellularity in the ancestors of animals. Protozoans capture prey by a variety of mechanisms, one of which is passive predation (the interception of prey that swim nearby). We studied the effectiveness of a passive protozoan predator, *Actinosphaerium nucleofilum*, at capturing *Salpingoeca helianthica*, a choanoflagellate with both unicellular and multicellular forms. *A. nucleofilum* capture prey on long axopods that radiate from the cell, and transport the prey along the axopods to the cell body, where they are engulfed in vacuoles. Prey can be lost during any of these steps. Frame-by-frame analysis of time-lapse videos taken during the feeding process showed that the feeding efficiency (proportion of prey entering the capture zone of the predator that were eaten) of *A. nucleofilum* was the same for single cells and colonies. Furthermore, there was no trend in feeding efficiency as a function of colony size. Thus, although some ciliates reject large choanoflagellate colonies but eat single cells, while some raptorial amoeboid protozoans ignore unicellular choanoflagellates but actively capture colonies, predation by passive predators might not have been important in the evolution of multicellularity.

P2-197 KUO, S*; PATEL, B; ORR, C; WARD, C; University of Missouri, Columbia, University of Southern California, Los Angeles, University of Colorado School of Medicine; *sharon0kuo@gmail.com*

Functional Morphology of the Anthropoid Primate Hindfoot

Reconstructing locomotor adaptations of fossil taxa is facilitated with a comprehensive understanding of the locomotor biology of their closely related extant relatives, which can elucidate broad patterns of locomotor evolution of a clade. For fossil primates, tarsal morphology should be especially useful since feet interact directly with the substrate on which an animal moves, and tarsals are relatively abundant in the primate fossil record. Specifically, the morphology of intertarsal joints is hypothesized to reflect specializations for movements that facilitate locomotion on arboreal and/or terrestrial substrates, with subtalar and transverse tarsal joints primarily responsible for inversion and eversion, and overall midfoot range of motion responsible for different foot postures. Hypotheses concerning the relationship between the shapes of, and movements at these joints, however, remain untested, especially in nonhuman taxa. This study presents 3D data on articular surface orientation and shape on virtual surface models of the calcaneus, talus, cuboid, and navicular in a diverse sample of anthropoids to identify osteological correlates of posture and motion at the talocrural, subtalar, and transverse tarsal joints. This study also presents an approach that will test these functional correlations using in vivo XROMM data of macaque locomotion on different substrates. The eventual goal is to combine the 3D morphometric results with the XROMM data to facilitate interpretations of primate locomotor evolution.

130-2 KUSTRA, MC*; KAHRL, AF; REEDY, AM; COX, RM; Univ. of Virginia, Stockholm Univ.; *mck8dg@virginia.edu*

Local Density of Conspecifics Affects Sperm Phenotypes in Wild Anolis sagrei Lizards

Theory predicts that males should invest more in ejaculate production when the likelihood of sperm competition is high, thereby increasing the chance of fertilization. However, ejaculates can be energetically costly, and increased investment into sperm production should only occur if there are fitness benefits associated with that increased investment. Growing experimental evidence suggests that sperm traits respond plastically to social environment. However, it is not known whether fine-scale spatial variation in the local density of male competitors or potential female mates corresponds to individual variation in ejaculate production. Using a wild population of brown anoles (*Anolis sagrei*), we tested the prediction that, as the risk of sperm competition increases (i.e., higher local density of male competitors), males will increase their total investment in their ejaculates (sperm size * sperm count). We also tested for correlations between sperm morphology and local density. We estimated the local density of male competitors and potential female mates for 202 individual males by taking into account all conspecific adults that were captured within a 5.8 m radius of an individual's own capture location. We found that length of the sperm midpiece increased with local density, whereas length of the sperm head and sperm count decreased with local density. Contrary to our predictions, we found that total investment in ejaculates decreased with local density. Our findings indicate that fine-scale differences in local density within a wild population can affect sperm count and various sperm phenotypes.

P2-122 KUSTRA, MC*; MACRANDER, J; REITZEL, AM; MARTINDALE, MQ; SKERGET, S; KARR, TL; Univ. of Virginia, Univ. of North Carolina, Charlotte, Univ. of Florida, Whitney Lab, Translational Genomics Research Inst., Kyoto Inst. of Technology; *mck8dg@virginia.edu*

Conservation of Proteins in the Evolution of Animal Sperm: a Cnidarian Perspective

Numerous studies have characterized the protein constituents of sperm in animals, but these have exclusively been within Bilateria. Here, we present the first analysis of a non-bilaterian sperm proteome belonging to the cnidarian *Nematostella vectensis* to provide insight into the evolution of sperm proteins. Using mass spectrometry, 1117 proteins were identified from isolated sperm that matched genes in the reference genome. We compared these proteins to the previously published *N. vectensis* egg proteome and found that they shared 532 proteins. We performed three separate BLAST searches against the previously published sperm proteomes of *Homo sapiens*, *Mus musculus*, and *Drosophila melanogaster*. We found that 68% of proteins in the *N. vectensis* sperm proteome had significant matches with at least one of the other three sperm proteomes: 32% with *D. melanogaster*, 58% with *M. musculus*, and 54% with *H. sapiens*. The most abundant Gene Ontology category among proteins shared between sperm proteomes was *flagellated sperm motility*. We found several sperm-egg interacting proteins as well as four outer dense fiber proteins, suggesting that these proteins may have conserved functions in sperm that date back to the cnidarian-bilaterian ancestor. We also identified two H1 histones that were not in the egg proteome suggesting they may be sperm-specific, supporting the current hypothesis that protamines evolved from H1 histones. Our comparative proteomic approach has revealed for the first time the complexity of a cnidarian's sperm and opens new questions regarding the evolution of these highly specialized animal cells.

76-3 KVALHEIM, M D*; REVZEN, S ; University of Michigan; *kvalheim@umich.edu*

Testing an extended "Posture Principle"

The locomotion of many animal species, mammalian quadruped walking and cockroach running as examples, appears to be associated with a "posture principle", wherein motion is restricted to a family of postures that is consistent across a range of speeds. Often this observation has been made in conjunction with the "templates and anchors" hypothesis that claims animals use control and dynamics to reduce the complexity of their body (anchor) motions to follow that of a simpler (template) system. Our recent work in dynamical systems theory suggests a universal, systematic method exists for anchoring templates that would follow such a "posture principle". We propose an assay to test for: (1) the presence of a posture principle; (2) the posture-based anchoring strategy our theoretical results suggest. If posture-based anchoring is found, it would suggest that position sensing could be used for anchoring with little or no support from velocity sensing, suggesting implications for the neuroanatomy and sensory physiology associated with locomotion.

P2-250 KWOK, R*; BUCKNER, A; RENN, SCP; Reed College, Portland OR; *renns@reed.edu*

Decreased Telomerase Activity in Conjunction with Life Stress in Astatotilapia burtoni

Telomeres, the repetitive DNA sequence at the end of chromosomes, are essential to maintain genome stability. It is known that telomeres shorten with age, but recent evidence indicates that, in humans, social stress may also shorten telomeres due to increased oxidative stress associated with high cortisol levels. Telomerase, the enzyme that repairs and lengthens telomeres, shows decreased activity in response to oxidative stress and reduced activity in chronically stressed humans. The teleost fish *Astatotilapia burtoni* presents an exquisite model for this field of research. Like other fish, they exhibit a high level of telomerase activity throughout life in many tissues and individuals experience different levels of social stress dependent on the dominance hierarchy. We tested the hypothesis that social stress in the form of a dominance hierarchy is correlated with telomerase activity. Analysis of telomerase activity with the TRAP assay revealed that subordinate fish, who are known to have higher levels of the stress hormone cortisol, had lower levels of telomerase activity than their dominant, less-stressed, dominant conspecifics. This study demonstrates that stressed *A. burtoni* also have repressed telomerase activity, the same pattern seen in humans, thus validating the use of these organisms for studying telomere and telomerase dynamics.

92-3 LABARBERA, K*; HAYES, KR; LACEY, EA; UC Berkeley; *klabarbera@berkeley.edu*

Environmental variation along an elevation gradient is associated with variation in extra-pair paternity, but not the use of a sexually selected signal, in dark-eyed juncos

Different environmental conditions are expected to generate different selective pressures. We investigated whether variation in climatic conditions, breeding season length, and number of offspring produced per season in populations of Dark-eyed Junco *Junco hyemalis* breeding at different elevations led to variation in extra-pair paternity and in the use of a sexually-selected male signal, the amount of white in the tail. Using 12 microsatellite loci, we found differences in extra-pair paternity rates among our populations, with a low extra-pair paternity rate (20% of nests) at high elevations, a high rate (57%) at middle elevations, and an intermediate rate (38%) at low elevations. Despite the elevational differences in the potential strength of sexual selection indicated by this variation in extra-pair paternity rate, we found no differences among elevations in mean values of tail white or tail white asymmetry, and no differences in the strength of the correlation between tail white and either of two indices of male quality, a measure of the honesty of the signal. Persistent gene flow among elevations may explain the lack of differentiation in the tail white signal.

109-5 LACEY, LM*; BENOWITZ-FREDERICKS, ZM; HATCH, SA; Bucknell Univ., Institute for Seabird Research and Conservation; *lml028@bucknell.edu*

Role of Nest Microclimate and Food Availability in Chick Development and Reproductive Success in Black-Legged Kittiwakes (Rissa tridactyla)

Seabirds are marine top predators often studied as bioindicators of climate shifts. Though many studies have analyzed the effect of macroclimatic variation on marine prey species availability and thus seabirds, few have analyzed effects of microclimate - fine spatial patterns of climate. We tested the hypothesis that localized temperature, humidity, and light at nests interact with food availability to alter black-legged kittiwake (*Rissa tridactyla*) chick developmental physiology, quantified via cloacal temperature measurements and growth rates, and reproductive success. We recorded temperature, humidity, and light exposure at individual nest sites during egg laying and chick rearing (May-August 2017) on Middleton Island, AK. Nests were located on "panels" with distinct compass orientation, insolation, and exposure to wind and rain. Panels housed ~25 nests, alternating between supplementally fed and unfed panels. 2017 microclimate data were compared to historical climate records and reproductive success from the same nest sites. Microclimate varied across the tower, with highest light exposure on the western face and lowest on the north. Humidity and temperature were inversely related, while light and temperature were positively related. Unexpectedly, nests at fed panels maintained higher average temperatures than adjacent unfed panels, suggesting variation in metabolism may influence nest microclimate. While food availability had a greater impact on growth and reproductive success, the data suggest microclimate may explain some variation in reproductive success. These data demonstrate another mode by which changes in climate may affect populations by altering individual physiology.

P1-45 LAI, AKM*; WAKELING, JM; BIEWENER, AA; Simon Fraser University, Harvard University; *adrian_lai@sfu.ca*

The functional role of human lower limb muscles during maximal sprint acceleration

Muscles generate force and energy required to produce and control movement. Three factors critical to a muscle's role are the mechanical demands of the movement (e.g. walking vs. running), location (e.g. proximal vs. distal) and muscle-tendon unit (MTU) design (e.g. short fibred vs. long fibred and presence of a tendon). These factors determine if a muscle favours a primary functional role such as storing elastic strain energy like a spring and generating force economically. During maximal sprint acceleration, the mechanical demands on the lower limb muscles transition from generating maximal positive work output during the start of the acceleration phase to maintaining net work output during the maximal steady sprint phase. Acceleration, therefore, allows us to characterise the functional role of muscles as mechanical demand changes within a specific motor task. We used a muscle-specific index-based approach in conjunction with computational simulations to characterise the role of the muscle-tendon unit (MTU) and muscle fibre in a subset of human lower limb muscles into four indices: strut-, spring-, motor-, and damper-like functions. Our index-based approach identified that both the MTU and muscle fibres in human lower limb muscles, which generated substantial mechanical work, exhibited greater motor-like function during the start of the maximal acceleration compared with the end. Further, despite possessing MTU designs favouring force economy, the MTUs of more distal muscles (i.e. ankle plantarflexors) also exhibited a significant shift from a motor-like function to a purely spring-like function as a steady speed was reached. We conclude that, although MTU architecture influences mechanical function, a muscle's functional role can vary substantially when mechanical demands, such as acceleration, must be met. (NIH AR055648).

P3-164 LAIRD, MF*; GRANATOSKY, MC; IRIARTE-DIAZ, J; REED, D; O'HIGGINS, P; ROSS, CF; University of Chicago, University of Illinois at Chicago, University of Illinois at Chicago, Hull York Medical School, University of York; *lairdm@uchicago.edu*

Covariation in primate facial form and jaw movement

Identifying relationships between mandibular morphology and jaw kinematic variables is critical for understanding how diet relates to feeding system form. Variation in primate prognathism has been related to differences in gape, bite force, and mechanical advantage of the masticatory muscles, but do jaw movements covary with facial prognathism? We examined covariation between chewing cycle form and facial form in three craniofacially-variant species of primates—macaques (*Macaca mulatta*), baboons (*Papio anubis*), and capuchins (*Sapajus apella*). Reflective markers were coupled to the mandible and cranium and their three-dimensional movements were captured using a Vicon motion capture system at 250 frames per second. A geometric morphometric approach was used to analyze three-dimensional covariation between rhythmic jaw movements and facial form. Chewing cycles were standardized to 99 frames and registered to a common facial form and the three-dimensional residual motion sequences were compared to facial variation of each species using a two-block partial least squares analysis. The results indicate a significant covariation between gape cycle form and facial form, such that taxa with greater prognathism had smaller gape cycles with reduced vertical displacement but larger lateral displacement. We hypothesize that smaller gape cycles in subjects with greater prognathism reflect tradeoffs between mechanical advantage and gape, suggesting that primates modify their jaw movements to maximize the mechanical advantage of their masticatory muscles. This covariation also suggests that differences in craniofacial morphology can affect jaw kinematics during chewing, and possibly other aspects of feeding kinematics.

P2-276 LAKE, JS*; ZORNIK, E; Reed College; *jelake@reed.edu*

Vocal Recognition Between Two Closely Related Species of African Clawed Frogs

Courtship vocalizations help animals find mates, contributing to reproductive fitness. Closely related African clawed frogs (genus: *Xenopus*) generate similar but quantitatively distinct mating calls, making them an excellent system for studying the evolution of courtship behaviors. Recent work has identified the neural basis for vocal differences between two closely related *Xenopus* species—*X. laevis* and *X. petersii*—but the degree to which females of each species can recognize these differences has not been investigated. In the current study, we monitored the behavior of female *X. laevis* frogs during exposure to one of three playback conditions: white noise, *X. laevis* advertisement calls, and *X. petersii* advertisement calls. Prior to behavioral testing, each *X. laevis* female was injected with human chorionic gonadotropin (hCG) to induce ovulation. We hypothesized that female *X. laevis* frogs would prefer the calls of males of their own species over *X. petersii* calls. We observed an initial several-hour period of inactivity, followed by an abrupt increase in locomotion and circling of the broadcasting speaker. No circling was observed during playbacks of white noise or *X. petersii* calls. *X. laevis* females spent the majority of their time near the speaker, both during playback and silent periods, but did not circle the area when the speaker was off. Our results indicate that female *X. laevis* can distinguish between *X. laevis* and *X. petersii* calls and prefer the conspecific calls. Female preference is limited to a window of peak sexual receptivity while the animal is actively ovipositing. These results suggest that acute changes in hormone levels can rapidly modify auditory circuits that process male vocal signals, enhancing the female's ability or motivation to find a mate.

35-1 LAM , E.L.*; GUNDERSON, A.R.; TSUKIMURA, B; STILLMAN, J.H.; Romberg Tiburon Center, San Francisco State Univ., California State Univ., Fresno; *ek3lam@gmail.com*

Variation in thermoregulation and linking whole organism behavior to thermosensory neurophysiology in the porcelain crab, Petrolisthes cinctipes

Small-scale shifts in species distributions are expected to occur under future climate scenarios for many species. These shifts can have consequences for population dynamics, and therefore it is important to understand when and why they occur. The intertidal crab *Petrolisthes cinctipes* currently experiences temperatures near lethal levels. However, the extent to which crabs move in response to temperature and the thermal thresholds that trigger migration to cooler microhabitats remain unknown. We tested for effects of body size and reproductive state on escape temperature (Tesc). In addition, we tested for the relationship between Tesc and the temperature of peak action potential firing frequency in sensory afferent neurons. We found that both size and reproductive state influence behavioral sensitivity to temperature. Small crabs tolerate significantly higher temperatures before they move to cool refuges (a higher Tesc) compared to large crabs. In addition, non-gravid crabs have significantly higher Tesc than gravid females. We also found that Tesc is positively correlated with peak neural performance of spontaneous action potentials (R^{2}"=0.26). We find that behavioral sensitivity to temperature varies consistently with size and reproductive state. These findings have implications for species persistence, rates of dispersal and community dynamics. The vulnerability of marine organisms to global change is predicated on their ability to utilize and integrate these physiological and behavioral strategies to promote survival and reproductive fitness; understanding these strategies will allow predictions of species distributions under warming and the potential for extirpation.

P1-58 LAMMERS, AR*; GERMAN, RZ; Cleveland State University, Cleveland OH, Northeast Ohio Medical University, Rootstown OH; *a.lammers13@csuohio.edu*

Bilateral asymmetry during suckling and swallowing in an infant pig model after superior laryngeal nerve lesion

The pharyngeal swallow uses a series of bilateral muscle contractions to propel a bolus from the mouth into the esophagus. Due to the evolutionary history of vertebrates, the airway crosses the food pathway, and can become compromised during a swallow. This is especially problematic for mammals, which have a high metabolic activity, and therefore cannot stop breathing while feeding. Stimulation of the superior laryngeal nerve initiates a swallow, and unilateral lesion of this nerve usually causes the airway protection mechanisms to fail. This nerve, however, has multiple brainstem connections, including ones to the central pattern generator for swallowing, suggesting a role greater than just triggering the swallow. Thus a unilateral lesion could produce asymmetric activity in muscles involved with suckling and swallowing, even though these are mid-line or bilaterally synchronous activities. In contrast, activities such as locomotion normally have asymmetric muscle activations. To test this hypothesis, we examined activity via electromyography in the right and left mylohyoid, geniohyoid, digastric, and thyrohyoid in four pre-weaning infant pigs while they drank milk. We examined feeding activity before and after a surgical transection of the right superior laryngeal nerve. Preliminary results suggest that after nerve lesion, asymmetry increases between right and left muscles. None of these muscles are supplied by the superior laryngeal nerve, or even by the vagus nerve (CN X). This suggests that disruption of this sensory input influences the swallowing network, including muscles supplied by ansa cervicalis (C1-3), as well as muscles that are not part of swallowing per se, supplied by CN V3.

129-1 LAMONT, EI*; EMLET, RB; Oregon Institute of Marine Biology, University of Oregon; *elamont@uoregon.edu*
The unique setular morphology of thoracic appendages on barnacle cyprids - form and function
Cyprids, the final larval stage of barnacles before settlement, are drag-based swimmers with six pairs of powerful thoracic appendages that beat sequentially through metachronal strokes. Like the swimming limbs of other crustaceans, cyprid limbs carry arrays of plumose setae - bristles with even smaller, short fibers (setules) distributed along two sides of each bristle. Setal arrays spread apart during power strokes (increasing the surface area and drag force of the appendage) and collapse together during recovery strokes (decreasing overall surface area and limiting drag). Cyprid thoracic appendages are unique among crustaceans in that the setules of adjacent setae are joined at their tips, forming a webbed array between setae. Three types of cross-linkage occur within and between biramous appendages: 1) within the setal fan of each podite, setules from adjacent setae connect at their tips and are also linked by a continuous thread running up the midline between adjacent setae; 2) between setal fans of podites the setules are joined at their tips; 3) between left and right appendages about eight thicker setules link medial setae of the endopodites. These cross-linkages occur in both thoracican and rhizocephalan clades. While most crustacean setae develop separately from individual sacs within the appendages of molting organisms, cyprid setae complete development beneath the cuticle of the nauplius, allowing the setular exoskeleton to fuse during development. The permanent webbing formed between setae is beneficial to drag-based swimming. Fused setules on appendages support a semi-rigid and highly ordered meshwork; this allows setal arrays to spread to a large surface area with low leakiness and promotes high thrust during power strokes of the paddle-like appendages.

81-1 LANE, SJ*; SHISHIDO, CM; MORAN, AL; TOBALSKE, BW; WOODS, HA; Univ. of Montana, Univ. of Hawai'i; *steven.lane@umontana.edu*
Pore things! Cuticular gas exchange by Antarctic sea spiders
Many marine organisms and life stages lack specialized respiratory structures, like gills, and rely instead on cutaneous respiration, which they facilitate by having very thin integuments. This respiratory mode may limit body size, especially if the integument also functions in structural support or locomotion. Sea spiders, or pycnogonids, are a basal group of marine arthropods that lack gills and rely on cutaneous respiration but still grow to large sizes. Sea spider cuticle is not solid but has many pores that cross the cuticle, which may play a role in gas exchange. Here, we tested two hypotheses for gas exchange in sea spiders: 1) oxygen diffuses directly across the cuticle, a common mechanism in aquatic insects, or 2) oxygen diffuses across pores in the cuticle, a common mechanism in vertebrate egg shells. We tested these hypotheses by modeling diffusive oxygen fluxes across all pores in the body of sea spiders, and then asking whether those total fluxes were significantly different from our separately measured metabolic rates. We estimated fluxes across pores using Fick's law incorporating measurements of pore morphology and oxygen gradients. Finally, we measured the scaling of size (length and diameter) and density of pores to test for effects of total pore area upon the animal's rate of flux. Flux across the pores scaled similarly to that of oxygen consumption, which strongly supports the second hypothesis. Larger species, therefore, need greater total pore area to facilitate greater diffusive oxygen flux across their cuticle. This likely presents a functional trade-off between gas exchange and structural support in large species, where the cuticle must be thick enough to prevent buckling due to external forces but porous enough to allow sufficient gas exchange. NSF PLR-1341485.

P3-139 LANE, S*; SEWALL, K; BREWER, V; Virginia Polytechnic Institute and State University; *samjl89@vt.edu*
Urbanization impacts nestling corticosterone but not offspring growth in song sparrows
Urbanization represents a dramatic and relatively rapid change in environment, which animals may cope with through phenotypic plasticity. In previous studies, it has been shown that male song sparrows (Melospiza melodia) in urban habitats show higher levels of territorial aggression than their rural counterparts. Such differences in male behavior could have consequences for offspring, as territorial aggression can be traded off against paternal care. Therefore, we compared nestling growth, corticosterone (CORT) levels, and survival among three rural populations (N = 15 nests/30 nestlings) and two urban populations (N=19 nests/45 nestlings) of song sparrows near Blacksburg, VA. We found that nest predation was higher in rural habitats, based on evidence of disturbance at the nest site. Additionally, we found that nestling baseline CORT levels were significantly higher in rural habitats, though there were no differences in overall nestling growth rates. Finally, there was a non-significant trend towards increased nest parasitism by brown-headed cowbirds in urban habitats. These findings suggest that male territorial aggression does have consequences for offspring CORT levels. Additionally, these findings suggest that there are differences in relative risks of predation and nest parasitism across rural and urban habitats, which could potentially drive variation in male territorial aggression.

S10-4 LAPIEDRA, Oriol; Harvard University; *olapiedragonzalez@fas.harvard.edu*
Behavioral adaptations to urban environments: an integrative perspective from individuals to species
Human-induced environmental changes such as urbanization are a threat for the persistence of numerous animal populations worldwide. Considerable progress has been recently made in identifying biological patterns resulting from the process of urbanization. However, unraveling the mechanisms driving these patterns has remained more elusive. Because behavior largely determines how animals interact with the environment, it has been hypothesized to be an important factor determining the success of animals in urban environments. Here I will argue how the study of animal behavior can largely contribute to our understanding of why some animals thrive in urban environments whereas others do not. First, I will first discuss some of the recent progress in studies of animal behavior in urban environments. Then, I will comment on the limitations hindering progress in our understanding of the mechanisms behind adaptation to urban environments such as the lack of an explicit temporal and spatial framework, the difficulty of assessing individual variation in behavior and the ethical issues associated with field experiments. Finally, I will argue that the factors that facilitate persistence differences among species are not necessarily the same than those factors favoring different individuals within a population. I will use Anolis lizards to illustrate how integrating different levels of information is crucial to obtain an integrative perspective of the role of behavior in the adaptation of animals to urban areas.

97-4 LAPSANSKY, AB*; IGOE, J; TOBALSKE, BW; University of Montana; *al113405@umconnect.umt.edu*

Effects of added payload on wingbeat kinematics in a flap-bounding bird

Diverse bird species exhibit a flap-bounding pattern in flight, wherein the bird periodically interrupts flapping by folding its wings and torpedoing through the air. According to theory, this flight style is aerodynamically inefficient, and, thus, its functional significance is unclear. Two hypotheses (*fixed gear*; Rayner, 1985; *minimal activation-deactivation*; Usherwood, 2016) predict that the major avian flight muscle, the pectoralis, should be used in a fixed manner to maximize efficiency (mechanical output:metabolic input). However, previous empirical research reveals that flap-bounding birds vary contractile behavior of their pectoralis across flight speeds and modes, and that wing kinematics provide a useful, non-invasive method for estimating this variation. Body mass fluctuates dramatically within birds as a function of migratory status, reproductive state and feeding rate. Also, wildlife researchers frequently add transmitters to birds to study movement patterns. The effects of variation in mass upon flap-bounding behavior and the implications for the muscle-based hypotheses are unknown. To begin to reveal the effects of mass upon flap-bounding, we added 10% of body weight to zebra finch (*Taeniopygia guttata*; n = 5) flying at 10 m s^{-1} in a wind tunnel. Consistent with predictions of both muscle-function hypotheses, the addition of weight did not cause significant changes in average wingbeat amplitude, wingbeat frequency, percent time in downstroke or downstroke velocity. Furthermore, weighted birds showed a significantly greater proportion of time spent flapping. However, within-individual differences in amplitude and downstroke velocity varied by up to 50% of the unweighted mean, which calls into question the degree to which the wingbeat can be considered "fixed".

78-1 LARABEE, FJ*; SCHULTZ, TR; POWELL, S; NMNH, Smithsonian Institution & George Washington University, NMNH, Smithsonian Institution, George Washington University; *larabeef@si.edu*

Morphometrics and Functional Morphology of Fungus-growing Ants

Mandibles are critical to the biology of ants, being the primary structures they use to interact with their environment. To explain why ants are so evolutionarily successful, it is critical to understand the relationship between mandible morphology and their ecological and mechanical performance. In this study, we examined the form and function of mandibles in fungus-growing ants, who display a great deal of mouthpart morphological diversity and variation in the fungus they cultivate. Using light microscopy and geometric morphometrics, we quantified head and mandible morphology for 70 species of fungus-growing ants in 13 genera. Additionally, we used X-ray microtomography to visualize mandible muscle morphology and lever geometry to indirectly estimate mandible performance. Our preliminary results indicate significant differences in head shape between agricultural systems of fungus-growing ants. Specifically, species with higher and leaf-cutting agricultural systems were found to have wider and longer heads, particularly along the posterior margin, compared with ants with lower and yeast agricultural systems. Coral fungus ants, represented by the genus *Apterostigma*, had heads that were significantly narrower than the other two morphological groups. These differences in head shape may reflect the mechanical requirements for processing different fungal substrates. Combined with a well-resolved phylogeny, these data can provide insight into the complex interactions between morphology, ecological performance, and patterns of biodiversity.

52-5 LARKIN, KL*; GOSLINER, TM; California Academy of Sciences; *klarkin@calacademy.org*

Through a veil of uncertainty: Resolving phylogenetic relationships of Indo-Pacific Arminid nudibranchs

Arminidae is a poorly supported family of nudibranchs within Cladobranchia that is grouped together by a single shared characteristic of an oral veil. This study aims to revise the phylogenetic relationships of *Armina* and *Dermatobranchus*, two dominant Arminid genera in the Indo-Pacific. Previous morphological phylogenies of Arminidae have placed these genera as sister taxa, citing *Dermatobranchus* as a more derived genus that has lost its secondary gill and performs gas exchange across its epidermis. Even with this distinction, new species of *Dermatobranchus* are often identified and described incorrectly as *Armina* due to ambiguous distinctions between genera and a large number of shared morphological traits. Recent morphological phylogenies have also illuminated cryptic species complexes within *Dermatobranchus*, which has added to the diversity and confusion surrounding this understudied group. This project represents the first comprehensive molecular phylogeny for Indo-Pacific Arminidae and includes over 100 specimens constituting a mix of roughly 50 described and undescribed species. We compared our new molecular phylogeny consisting of 16s, 28s, and COI genes to the existing morphological phylogeny of Arminidae to determine if the characters used for species delimitation are sufficient, and where species boundaries occur across and within genera.

66-1 LASALA, JA*; HUGHES, C; WYNEKEN, J; LASALA, Jacob; Florida Atlantic University ; *jlasala1@fau.edu*

Potential for marine turtle promiscuity to counteract extreme environmental effects

Species that display temperature dependent sex determination are at risk due to increasing global temperatures. Marine turtles are especially at risk due to the high feminization of the offspring due to these increases that may skew the adult sex ratios. As marine turtle individuals are widely distributed and males remain in the ocean, a functional alternative is sought: breeding sex ratios (BSR). One way to examine BSR is to determine the number of males that contribute to nests. Previously, we examined the BSR for loggerhead turtles nesting in the Gulf of Mexico in Florida. Our research suggests that there are many males contributing to these nests. We hypothesize that this high quantity of males might be counteracting the effects of skewed sex ratio. However, the previous research focused on individual turtles and our estimate of BSR could not account for multiple mating events. We aim to correct this by examining nests laid by turtles that returned to nest multiple times in 2016. We sampled 16 repeating females and a subset of their subsequent nests (625 hatchlings). We found that in the majority of nests females did not mate again in between clutches, suggesting that in this region our estimate of the BSR was accurate. It also confirms long standing theory that females mate at the beginning of the breeding season and then do not mate throughout the nesting season. It is imperative to establish how mating affects the population structure of these populations, so we can identify how they might behave before extreme environmental effects are evident.

39-2 LASCALA-GRUENEWALD, DE*; HAGGITT, TR; SHEARS, NT; Univ. of Auckland; *dianalg11@gmail.com*

Small Marine Reserves do Not Provide a Safeguard Against Overfishing

Marine reserves provide protection to harvested species within their boundaries, and can reverse the ecosystem-level effects of fishing pressure. This has been well documented in the Cape Rodney-Okakari Point (CROP) marine reserve in northern New Zealand. However, marine reserves may be less effective in protecting mobile species that experience low or highly sporadic recruitment, especially when those reserves are small. In this study, we present recent monitoring data from the CROP marine reserve and two other nearby reserves, showing large-scale declines in populations of the rock lobster *Jasus edwardsii*. Current lobster biomass within the reserves is less than 20% of historic levels, while biomass outside the reserves is only 1% of historic levels within the reserves. Adult *J. edwardsii* undertake seasonal migrations beyond the reserve boundaries, and so we hypothesized that the observed declines are likely a result of sustained fishing pressure targeting the reserve boundaries in concert with an extended period of low recruitment. To explore the effects of low recruitment on lobster density within the reserves, we employed an agent-based demographic model. We hindcasted the levels of recruitment at each reserve over the past 10-20 years. Then, we used the model to estimate the recruitment levels that would have been required to sustain lobster densities given current fishing pressure. We found that either consistent, low recruitment, or higher, more sporadic recruitment would be required for sustainability. Together, our results suggest that for mobile species with low or highly variable recruitment, marine reserves must be large enough to encompass the totality of seasonal movements in order to be effective.

23-7 LATTIN, CR*; GALLEZOT, J-D; CARSON, RE; Yale University; *christine.lattin@yale.edu*

Individual variation in dopamine physiology predicts behavioral resilience to a chronic stressor

Individuals able to persist without changes in physiology and behavior in the face of external disruptions can be said to be *stress resilient*. The neural mechanisms for this resilience are poorly understood, but vitally important, given that stressors such as climate change, habitat destruction and species invasions now affect all animals. Although the neurotransmitter dopamine is best known for its role in reward-motivated behavior, the mesocorticolimbic dopamine system of the brain also responds strongly to stressors. We hypothesized that stress resilience may involve limiting the effects of powerful neuromodulators like dopamine on the brain. To test this hypothesis, we examined whether striatal D_2 receptor binding potential (BP, assessed using positron emission tomography imaging with the D_2 antagonist ^{11}C-raclopride) was correlated with behavior in response to chronic captivity stress in wild-caught house sparrows (*Passer domesticus*, n=15). D_2 BP is an *in vivo* integrated measure of dopamine physiology, reflecting both synaptic dopamine concentrations and numbers of inhibitory dopamine D_2 receptors in striatum. We found that striatal D_2 BP 24 h after capture was not correlated with initial behavior, but did predict the frequency of multiple behaviors several weeks later. Specifically, individuals with higher D_2 BP (=a less reactive dopamine phenotype, with less synaptic dopamine and/or more D_2 receptors) spent less time engaged in anxiety-related behavior and more time feeding compared to individuals with lower BP. These data support our hypothesis that a reduced dopamine response may be associated with stress resilience, and demonstrate the usefulness of *in vivo* imaging for revealing relationships between individual variation in neuroendocrine phenotypes and behavior.

P1-248 LAU, HJ*; SWANSON, RE; PEREZ, JH; CHEAH, JC; KRAUSE, JS; MEDDLE, SL; WINGFIELD, JC; Univ. of California, Davis, The Roslin Institute, Univ. of Edinburgh; *hjlau@ucdavis.edu*

Influence of the environment on stress physiology: Seasonal differences in the stress response in migrant and resident free-living white-crowned sparrows (Zonotrichia leucophrys)

Corticosterone is the primary glucocorticoid regulating physiological responses to stressful stimuli in birds and is regulated through the hypothalamic-pituitary-adrenal (HPA) axis. Environmental conditions are known to influence stress physiology with higher corticosterone secretion often selected for in birds coping with harsher unpredictable conditions. Two closely related subspecies of white-crowned sparrow (*Zonotrichia leucophrys*) are exposed to different fluctuations in environmental conditions. Migratory Gambel's white-crowned sparrows (*Z. l. gambelii*) breed in the Arctic and are faced with an unpredictable inclement environment. Resident Nuttall's white-crowned sparrows (*Z. l. nuttalli*) in coastal California are found year-round in temperate conditions with little exposure to environmental fluctuations. Here we tested the hypothesis that the corticosterone response to capture and restraint stress would be higher in migrants compared to residents. Blood samples were collected during breeding, pre-basic molt, and during wintering and analyzed by radioimmunoassay. Corticosterone in males was higher in migrants compared to residents during breeding and pre-basic molt while this relationship was reversed for the wintering stage. In females, corticosterone was higher in residents during winter while no other differences were found. Differences between the subspecies suggest that ecological and environmental conditions play a major role in determining HPA axis activity. Studies are currently underway to understand the mechanisms underlying these differences.

70-8 LAUDER, GV*; AKANYETI, O; CASTRO-SANTOS, T; DISANTO, V; DONG, H; GOERIG, E; LIAO, J; WAINWRIGHT, DK; Harvard Univ., Aberystwyth University, USGS S.O. Conte Anadromous Fish Research Center, Harvard Univ., Univ. of Virginia, USGS S.O. Conte Anadromous Fish Research Center, University of Florida; *glauder@gmail.com*

Comparative Undulatory Kinematics in Swimming Fishes: Quantitative Database from a Diversity of Species

Biologists studying fish locomotion have had a preoccupation with producing classifying schemes.For example, the classical scheme of Breder divides undulatory fish kinematics into categories based on modes of locomotion named after exemplar species.Fishes that are believed to swim with relatively large undulations of the entire body are referred to as "anguilliform" after the eel *Anguilla*, while fishes with progressively longer wavelength undulations are termed "subcarangiform"," carangiform", and "thunniform" (after tuna, *Thunnus*).Under this scheme, lateral amplitude oscillations of the anterior body decrease progressively from eels to tuna. In order to provide data for a comparison of undulatory swimming kinematics in fishes, we have assembled a quantitative data set of midline body bending kinematics across 34 species including amphioxus, eels, sharks, and tuna.High-speed video data were obtained from both controlled laboratory flow tanks and a field-based high-speed flow tank where fish can exhibit natural high-speed migratory locomotor behavior. We measured 200 body midline coordinates from head to the tail throughout one tail beat cycle.Analysis of midline kinematics shows that, at slow swimming speeds, there is considerable similarity among species even as diverse as eel and tuna.At high swimming speeds, kinematics often change with higher amplitude motion of the head.In the future we plan to create an open-access multi-species kinematics database for use in comparative studies of fish swimming kinematics and for programming fish robotic systems.

S1-2 LAUMER, CE; EMBL-EBI; *claumer@ebi.ac.uk*

Apologies and prospects for metazoan phylogenetics in the genomic era

Despite the deluge of data generated by over a decade of highly parallel sequencing, molecular approaches to date have failed to deliver a fully-resolved metazoan phylogeny. Here, I attempt a partial explanation of this paradox, illustrating some outstanding dilemmas of the discipline with two empirical datasets, and outlining prospects for their ouster. Firstly, incorporating new genome assemblies spanning the extant diversity of Placozoa, I investigate pre-bilaterian relationships. I see strongly supported discordance among gene sets for the position of Placozoa, but show that genes that pass a sensitive compositional heterogeneity test favor a Cnidaria+Placozoa clade, suggesting the familiar position of Placozoa outside a Bilateria-Cnidaria clade is a compositional artifact. I also observe strongly supported discordance vis-à-vis the identity of the earliest-branching animal clade, depending on whether the matrix is encoded as amino acids or as Dayhoff groups. In a parallel analysis, I examine pan-metazoan relationships, with a large (165+ taxa) matrix comprising genome or transcriptome assemblies from all animal phyla (excluding Mesozoa). I discuss strategies for overcoming multiple sources of error at this scale, e.g. by considering the value of taxon-specific gene sets, and the detrimental impact of rogue or data-poor taxa on convergence in Bayesian mixture model analyses. Finally, I present a new technique for amplifying long-insert (3-10 kb) genomic libraries with little coverage bias via PCR from picogram-scale input DNA quantities. Combined with nanopore sequencing, we show the potential of this technique to fill in the remaining gaps in genomic resources across the animal tree of life, by enabling highly contiguous reference genome (and metagenome) assemblies derived from single meiofaunal animals.

24-2 LAURENCE-CHASEN, JD*; RAMSAY, JB; BRAINERD, EL; University of Chicago, Westfield State University, Brown University; *jdlaurence@uchicago.edu*

Complex Prey Processing in a Freshwater Stingray, Potamotrygon motoro

Potamotrygon motoro, a freshwater stingray from the Amazon river, is thought to process insect prey with asymmetric, shearing jaw motions characteristic of mammalian masticators. However, the cartilaginous elements of the batoid feeding apparatus (chondrocranium, hyomandibulae, Meckel's cartilage, palatoquadrate) are obscured by several layers of tissue and difficult to visualize with standard video cameras. Accordingly, we used marker-based XROMM (X-ray Reconstruction of Moving Morphology) to visualize and measure the motions of *P. motoro's* cranial cartilages during processing. We find that *P. motoro* utilizes two kinematically distinct types of chew cycles to break down tough prey. In addition to standard compressive chews, *P. motoro* occasionally performs exaggerated chews we term overbite (OB) cycles. In OB cycles, the upper jaw rotates past regular occlusion, shearing the prey along the curved lower jaw tooth plate in a manner similar to the propalinal chewing observed in some mammals. OB cycles are facilitated by extremely flexible jaw symphyses and what appears to be independently controlled upper and lower jaw depression. Also, we find variable asymmetry in the magnitude of left and right jaw joint rotation, as well as in whole-jaw deviation from midline during protrusion. The latter is made possible, in part, by the additional degrees of translational freedom provided by the angular cartilages.

P3-176 LAURENT, CM*; AHMED , SI; COOK, RB; DE KAT, R; University of Southampton; *c.laurent@soton.ac.uk*

Inside a Feather II: 3D quantification of laminar layup in a bird feather shaft.

Feathers have been evolving for more than 130 million years under selection pressures to become light, stiff and strong. However, detailed investigation into their internal material structure (and properties) is still lacking. Previously, we have shown that the laminar structure of the feather shaft varies around its circumference and along its length. This is based on the observation of pseudo-ellipsoid voids, which can be observed with Synchrotron Radiation Computed Tomography (SRCT) at ultra-high resolution (~300 nm).

Here, we present the orientations of these ellipsoids and map how they change with spatial location. By doing this, we are able to quantify the laminar structure around and along the feather shaft for the first time using a repeatable method. These results are an important step forward in analysing the feather shaft as a laminar composite, so that future work can explore the form:function relationship of this complex structure in more detail.

24-3 LAW, CJ*; SLATER, GJ; MEHTA, RS; LAW, Chris; Univ. of California, Santa Cruz, University of Chicago; *cjlaw@ucsc.edu*

Small and Slender: Evolutionary Shifts Towards Elongate Body Plans within Mustelidae

Morphological innovations have been extensively discussed as drivers of lineage diversification. In this study, we examine the role of body size and shape and their effects on the evolution of musteloids. Previous work revealed musteloids exhibit decoupled diversification dynamics driven by increased clade carrying capacity in the branches leading to a subclade of mustelids as well as a lack of correspondence in patterns of body length and body mass evolutionary rates within the decoupled mustelid subclade. These results suggest that body elongation could be an innovation for the exploitation of novel Mid-Miocene resources, resulting in increased species richness of "elongate" mustelids. To further test this hypothesis, we first examined the evolution of body size in musteloids and find that small body size is associated with primarily mustelines and some gulonines and ictonychines. We then quantify body shape using the vertebrate shape index, a metric that describes a continuum of body shape from disc- or football-shaped bodies to elongate forms and allows for examination of the underlying morphological changes that can drive the evolution towards more elongate body plans. We found that mustelid crown clades Helictindinae, Martinae, Ictonychinae, Mustelinae and Lutrinae exhibited shifts towards more elongate shape optima and that weasels consistently shifted towards the most elongate optima. These results support the hypothesis that body elongation potentially served as a morphological innovation allowing weasels to specialize on subterranean rodents.

137-8 LAZEBNIK, M./B.*; KUNZ KOLLMANN, E.; LEDLEY, F./D.; Bentley University , Boston's Museum of Science; *mlazebnik@bentley.edu*

Implementing Informal Science Learning into Biology Curriculum for Non-Majors to foster Socio-Scientific Argumentations Skills

For non-majors, business students, biology class might be the last exposure to science, so the idea is to maximize their experience and engage them with science. Our overarching goal is to incorporate the informal science learning into our curriculum to acquire a better understanding of how informal learning experience promotes scientific reasoning ability, evidence based science skills, and influences formal classroom learning. As many scientific advances spark ethical debates and changes in government policies, one often overlooked task of science education for nonmajors is to develop their ability for socio-scientific argumentation. Socio-scientific argumentation is often overlooked as a major component of developing scientific-evidence based skill in non-majors college classrooms. Here we present a unique project where business students learn socio-scientific argumentation skills in informal science learning environment of the Provocative Questions Exhibit at Boston's Museum of Science (MOS) to supplement the curriculum of Human Biology Course at Bentley University.

P3-119 LE, MT*; GARVIN, CM; FRANCIS, CD; California Polytechnic State University, SLO; *MYLAN.THI.LE@GMAIL.COM*

The influence of natural sounds on California ground squirrel (Otospermophilus beecheyi) vigilance and predator detection.

Many animals rely on the acoustical environment for functions spanning mate attraction, navigation and predator and prey detection. Research suggests that environmental acoustics can greatly influence the propagation and reception of biologically relevant sounds, potentially interfering with the ability of animals to interact with their environment. We sought to determine whether natural sounds influence vigilance and predator detection in the California ground squirrel (*Otospermophilus beecheyi*). In a manipulative field experiment, vigilance and foraging behavior was recorded under three conditions: a playback of river rapids noise, a playback of cicada chorus noise and a silent control playback. Additionally, within each treatment, we measured flight initiation distances (FID), defined as the distance at which an animal flees from an approaching threat. We measured the squirrels' FIDs using the approach of a robotic coyote, thereby simulating a common predator in our study area. We found that squirrels were more vigilant during river rapid playback relative to control and cicada chorus treatments. We found mixed results regarding the influence of sound treatments on foraging rates and no difference in FIDs among the three treatments. To our knowledge, our results are the first to demonstrate that natural sounds can influence vigilance. Our results also support recent studies demonstrating increased vigilance in the presence of low-frequency background noise due to traffic or wind farms. Whether natural sounds influence other key behaviors is ripe for future studies.

47-1 LEACH, WB*; PERES, R; MACRANDER, J; REITZEL, AM; University of North Carolina, Charlotte, University of Hawaii Cancer Center; *wroger11@uncc.edu*

Transcriptomic changes in response to a diel light-dark cycle in Nematostella vectensis, an estuarine anemone

Nematostella vectensis, a burrowing estuarine anemone, exhibits 24 hour rhythmic cycles in behavior and gene expression. This cycling may be a direct photoresponse to the exposure of light, a molecular circadian clock, or a combination of these two factors. Although N. vectensis, like all organisms inhabiting shallow aquatic environments, experience diurnal lighting conditions, the relative roles of the circadian clock and the photoresponse in driving gene expression remain poorly understood. Here, we compare gene expression from N. vectensis under 12:12 light:dark (LD - diel) and 12:12 dark:dark (DD - disrupted) conditions. Our analysis measured transcriptome-wide oscillations in gene expression to identify genes exhibiting cyclic expression and allowed us to determine which of these continue to have differential expression after removal of the light cue. Comparisons of LD and DD exposed animals revealed approximately 700 genes with significant differences in expression in LD cultured animals, with more than 97% of these losing differential expression after removal of light cue. The analyses of differentially expressed genes revealed an abundance of signal transduction pathways and regulation of transcription processes upregulated during the daytime hours of the LD cycle. This analysis provides a powerful resource to evaluate the impact of light cycling on various molecular pathways in cnidarians, only a portion of which may be regulated by a circadian clock.

104-1 LEASI, F*; SEVIGNY, J; LAFLAMME, EM; HOCHBERG, R; NORENBURG, JL; THOMAS, KW; University of New Hampshire; *francesca.leasi@gmail.com*

Disentangling biodiversity in the growing field of environmental genomics: role of traditional taxonomists

Biodiversity is globally recognized as a foundation of ecosystem health, and accurate estimates of biodiversity are valuable to informing ecosystem monitoring programs and understanding ecosystem functioning. Yet, a standard operational procedure that assesses biodiversity accurately and with consistency has not been established. This is especially true for meiofauna, which is a hyperdiverse community of microscopic organisms living within aquatic sediments. Recent studies suggest that metabarcoding - DNA sequence analysis of a common "orthologous" gene - is a cost- and time-effective method to understand meiofauna diversity. The efficiency of metabarcoding meiofauna has not been well tested, with most analyses coming from samples of select community members (nematodes, copepods). Here, we show the results from analyses that test a higher diversity of community members. We compare the diversity of seven phyla by considering (i) single individuals analyzed with traditional taxonomy and species delineation models applied on a marker gene, and (ii) environmental genetics with operational taxonomic units and sequence variants-based assessments. Outcomes suggest that metabarcoding is biased towards certain taxa. This study supports the urgency of improving the environmental genomics (multilocus) approach while working alongside traditional taxonomists to correctly estimate meiofaunal biodiversity.

P2-97 LEDESMA, D*; SCARPETTA, S; University of Texas; *ledesma-david@utexas.edu*

A fossil alligator lizard from southern California

I performed a phylogenetic analysis of gerrhonotine lizards in an effort to elucidate the phylogenetic position of a well preserved fossil skull. The fossil was collected from Pliocene sediments in the Anza-Borrego Desert State Park in southern California. The results of my analysis allow me to refine the taxonomic resolution of the fossil skull, which represents the first fossil to be assigned to the gerrhonotine genus *Elgaria* using apomorphies. The age of the fossil is constrained by magnetostratigraphy and falls within a time period of rapid diversification of species of *Elgaria* based on previous molecular estimates. I addressed the lack of comparative skeletal data for extant gerrhonotine species through the use of high resolution x-ray computed tomography (HRCT).The lizard group Gerrhonotinae contains over 50 extant species which inhabit diverse environments across western and south-central United States, Mexico, and Central America. Although previous authors examined the osteology of species within Gerrhonotinae, their studies were limited because skeletal data are exiguous or nonexistent for many extant species. I obtained permission from museums to borrow alcohol-preserved gerrhonotine specimens for HRCT scanning. I built a diverse comparative dataset of the osteology of 17 species, representing the major clades within the group. This is the most diverse sample of osteological data for species of Gerrhonotinae to date. HRCT permitted me to examine morphology that was obscured on the physical fossil and analyze the phylogenetic placement of the fossil skull. My preliminary results indicate that the fossil has a close relationship with *Elgaria velazquezi*. The close affinity of the fossil with a species endemic to the Baja California peninsula provides evidence for deciphering the diversification and paleobiogeography of *Elgaria*.

P1-176 LEE, M*; PECHENIK, JA; PIRES, A; Dickinson College, Tufts University; *leemax@dickinson.edu*

Effects of diet quality and pH on growth, mortality, and shell strength in larvae and juveniles of the marine gastropod Crepidula fornicata

Ocean acidification metabolically stresses marine organisms, especially those that must expend energy to deposit calcium carbonate shells and skeletons. Nutrition may interact with pH to exacerbate or counterbalance acidification effects in early developmental stages. Previous work had indicated that growth of larvae and juveniles of the caenogastropod *C. fornicata* is resilient to acidification within the pH range of 7.6-8.0 when animals are given a high-quality diet of *Isochrysis galbana* (ISO). We therefore reared larvae and juveniles at two levels of pH (7.6 or 8.0) and on either a diet of ISO or a poorer-quality diet of *Dunaliella tertiolecta* (DUN), and measured larval and juvenile growth and mortality as well as juvenile shell strength. Larvae grew about 30% faster, and juveniles grew about 50% faster, on ISO than on DUN. However, larvae and juveniles grew at similar rates at pH 7.6 and 8.0 within each diet treatment. Survivorship of both larvae and juveniles was not affected by pH, but was higher on a diet of ISO than of DUN. We thus did not find evidence for interaction of diet quality and pH in larval or juvenile growth or mortality. Juvenile shell performance was tested by measuring crushing force after 20 d of postmetamorphic growth in each combination of diet and pH. Shells were 25% weaker at pH 7.6 than at 8.0 for individuals that were fed ISO, and 55% weaker at pH 7.6 than at 8.0 for individuals that were fed DUN, even though mean shell lengths did not differ between pH levels within each diet treatment. Rigorous assessment of the interaction of diet and pH on shell performance will require further study of how shell strength scales with age and size. (Supported by NSF 1416690.)

76-5 LEE, D/V*; ISAACS, M/R; COMANESCU, T/N; University of Nevada Las Vegas; *david.lee@unlv.edu*

Step length constraints influence compliance during human walking

Legs are traditionally considered to be compliant during running and rigid during walking. This derives from the paradigm of a compliant spring-loaded inverted pendulum (SLIP) mechanism during 'bouncing' steps of running and a rigid inverted pendulum mechanism during 'vaulting' steps of walking. We examined this dichotomy by combining experimental step length manipulations in walking humans with a serial actuator-spring model of measured leg dynamics to determine changes in the modeled radial-leg spring constant with step length. Our model finds the radial-leg spring constant that minimizes the total actuator work. Across walking step length conditions from shortest to longest, the radial-leg spring model shows that stiffness decreases as a reciprocal function of leg excursion angle. This curve fit of stiffness versus excursion angle reveals a horizontal asymptote at 19.5 kN/m, which matches the radial-leg spring constant for running, indicating a confluence with the compliance of running legs at unnaturally long walking step lengths. At the other extreme, as step lengths become unnaturally short the vertical asymptote of this fitted curve is 38 degrees - indicating that human legs become arbitrarily stiff as they approach the excursion angles used by rigid-legged passive dynamic walkers at the upper limit of their walking speed. However, at natural step lengths, humans achieve compliant walking with a relatively modest 25-50 percent increase in radial spring constant, which does not support a qualitative change from compliant-legged running to rigid-legged walking at the step lengths and speeds typically used by human walkers.

P3-118 LEFAUVE, MK*; HERNANDEZ, LP; George Washington University; *mlefauve@gwmail.gwu.edu*

Behavioral Baselines in Goldfish Carassius auratus

Behavioral plasticity is one of the characteristics that allow organisms to adapt to their surroundings. Such individual variation in behavioral traits is considered adaptive due to the heterogeneity of habitats. However, this view can be limiting when one is interested in more than just individual differences in response to a changing environment. Analysis of behavior is a powerful, noninvasive technique that can be used to allow researchers to expose organisms to a variety of stimuli while eliciting quantifiable responses. However, in order to accurately predict responses to stimuli, assays need baseline information that play a key role in creating species-wide averages. This study assessed the use of basic behavioral responses to generate a species-specific baseline that will be used in future studies. Using goldfish, this study reevaluated the value of scototaxis as anxiety-like behavior and assessed gregarious-like behaviors in an open field task. Experimental tank usage was also assessed as a baseline measure of overall activity. All the behavioral criteria were analyzed using Ethovision for the percent time moving during the trial, experimental arena location, and overall swimming velocity. Preliminary results suggest that these behavioral parameters are quick and efficient measures to generate species-specific basic behavioral baselines that can be later utilized to assess deviation from a norm in a variety of experimental situations.

S10-3 LEFEBVRE, Louis*; DUCATEZ, Simon; SAYOL, Ferran; SOL, Daniel; McGill University, Montreal, University of Sydney, Sydney, Autonomous University of Barcelona, Barcelona, Autonomous University of Barcelona, Barcelona; *louis.lefebvre@mcgill.ca*

Are Urban Species City Specialists or Habitat Generalists?

In an increasingly urbanized world, understanding how animals respond to artificial habitats has become a priority of conservation strategies. Here, we use the IUCN database on exploitation of artificial habitats for 28 688 species of terrestrial vertebrates to plot the phylogenetic distribution of urbanization tolerance. We then ask if urban dwellers are city specialists or instead generalists that thrive in all six types of artificial habitats listed in the IUCN database. We show that, in birds and mammals, urban exploiters tend to be habitat generalists and that the species that use cities frequently use rural gardens, but to a lesser extent other artificial habitats like arable land, pastureland, plantations or heavily degraded former forests. In reptiles and amphibians, however, city dwelling species tend to be those that also exploit arable land and pastures rather than rural gardens. Our results highlight the fact that responses of different taxonomic groups to artificial habitats might not necessarily be the same and that there might be different routes to becoming a city dweller.

109-1 LEIGH, SC*; PAPASTAMATIOU, YP; GERMAN, DP; University of California, Irvine, Florida International University ; *scleigh19@gmail.com*

Omnivorous Sharks? An Analysis of Bonnethead Shark Digestive Physiology Provides Evidence for Seagrass Digestion and Assimilation

Sharks, which are uniformly considered carnivores, have guts optimized for digesting a high-protein diet. Omnivores, on the other hand, also digest plant material, and thus, face the difficulty of digesting carbohydrates and foods sheathed in rigid cell walls. The bonnethead shark (*Sphyrna tiburo*) is known to consume copious amounts of seagrass (up to 62% of gut content mass in juveniles of some populations), yet maintains a gut that morphologically reflects its carnivorous ancestry. We investigated the digestive function of *S. tiburo* in order to determine whether they can digest and assimilate nutrients from seagrass (*Thalassia testudinum*). *S. tiburo* were held in captivity and fed a 90% seagrass diet equaling 5% of their body weight daily for three weeks. By growing the seagrass in a separate tank containing enriched $^{13}CO2$, the seagrass tissues became labeled with ^{13}C. Weekly blood draws from the sharks consuming the labeled seagrass show (via stable isotope analysis) that they are assimilating carbon from the labeled seagrass. Digestibility analyses show that $58.6 \pm 2.9\%$ of the total organic matter in the 90% seagrass diet is digested by *S. tiburo*. A spike in β-glucosidase activity (a cellulose-degrading enzyme) was recorded in *S. tiburo* hindguts. Hence, whether or not the ingestion of seagrass is incidental, these results provide explicit evidence that bonnethead sharks, animals previously thought to be solely carnivorous, can benefit from the digestion of seagrass, which leads one to re-evaluate the ecological role of *S. tiburo* in its coastal habitats.

114-4 LEITCH, KJ*; VAN BREUGEL, F; DICKINSON, MH; California Institute of Technology, University of Washington; *kleitch@caltech.edu*

Long-distance navigation of Drosophila melanogaster in the field

Long-distance journeys can drive gene flow, influencing ecology and evolution. Though animals such as monarch butterflies shed light on the extremes of navigation, it is also important to study navigational generalists, whose journeys likely depend on a conserved and widespread neurobiological toolkit. Jerry Coyne and colleagues showed, nearly 30 years ago, that *Drosophila* species can fly many kilometers across open desert, likely in a single night. This prompts many new questions: we here examine whether fruit flies can maintain straight headings over long distances, and whether azimuthal heading is influenced by particular celestial cues. We also aim to uncover rules governing flies' olfactory plume tracking in the field. To address these questions, we are performing releases of lab reared, wild type *Drosophila melanogaster* from the center of a dry lakebed in the Mojave Desert. We have developed baited fly traps equipped with machine-vision cameras, which provide estimates of flies' arrival times. The transit times we record suggest that most flies must fly with relatively straight trajectories at speeds ranging from 1.2 to 1.8 meters per second, largely irrespective of wind direction. That these average speeds are achieved over the visually homogeneous lakebed suggests flies may use celestial cues to maintain straight headings. Our field data are also intriguingly inconsistent with the positive anemotaxis fruit flies generally exhibit in laboratory wind tunnels, yet arrival times at our crosswind traps suggest flies are not passively blown downwind. To help interpret these data, we have constructed an agent-based model to simulate flights across the dry lakebed.

131-3 LENARD, A.N.*; GIFFORD, M.E.; University of Central Arkansas; *angie.lenard17@gmail.com*

Biochemical Mechanisms Influencing Countergradient Variation in Lizard Development

Countergradient variation occurs across environmental gradients when environmental and genetic influences on a phenotype oppose each other. An example of this phenomenon is the inherently faster growth rates observed in animals from higher latitudes compared to their low latitude conspecifics. Enhanced growth is hypothesized to be advantageous for ectotherms from cooler climates to compensate for a shorter growing season and depressed metabolism. *Sceloporus consobrinus*, the prairie lizard, is an excellent system to study the underlying mechanisms of countergradient variation in growth due to its broad latitudinal range. This study compares *S. consobrinus* from Missouri to those in Arkansas and provides evidence for countergradient variation in embryonic development. Lizards from Missouri hatched out larger and exhibited shorter incubation times than those from Arkansas. At the same stage of development, embryos from Missouri were larger than those from Arkansas and had less residual yolk, but no differences in metabolic enzymatic activity were observed. This study provides additional support that yolk assimilation rates play a major role in countergradient development.

P1-155 LENT, DD*; MENDOZA, A; Cal State Univ. Fresno; *dlent@csufresno.edu*

Modeling visual perception, learning, and memory of wood ants navigating in naturalistic environments

Through simulation we characterized how visual cues that ants use are extracted, prioritized and stored during navigation. A foraging model simulates navigation in a procedurally generated environment where the visual cues could be precisely characterized. In these environments, our algorithms extracted and stored the visual cues that were available during a single Levy walk foraging event. Following a random foraging event, the success on subsequent foraging bouts using the stored information was examined. When we examined subsequent foraging walks we found the success of the simulated ant in finding the goal location using only a particular cue or a combination of cues depended on two factors - the length of the route and decay rate of information in a memory network. To further explore this, we simulated the foraging event over various sampling points and implemented linear or exponential decay in the networks storing the information. Our data suggests that the optimal strategy is to sample and store around 1000 points along the foraging route, independent of scale, with a network subjected to exponential decay. These parameters resulted in a stored representation that allowed the simulated ant to best find the goal on subsequent foraging bouts. We then produced several novel random foraging walks with the same goal location. The subsequent walks for these foraging events had similar success demonstrating sufficient information was stored and resulted in idiosyncratic foraging routes due to the varied information encountered during the random walk. Additionally, we explored how multiple subsequent walks updated and modified memory to produce more robust walks over time. Lastly, we compared the success of subsequent of the model when foraging in sparse and cluttered environments.

P1-9 LENT, DD; RAWAT, M; MÜLLER, UK*; CSU Fresno; *umuller@csufresno.edu*

A Capstone Case Study as Review for an Introductory Biology Class

Case studies have become an established approach to engage students and to practice problem solving skills. This case study was developed to serve not just as a means to convey information and practice skills in a high-impact way, but also as an alternative to traditional review sessions before the final examination. This case was developed for use in the final two to three class periods at the end of the semester. It uses primary research literature and news articles to explore the current public health "crisis" brought on by the emergence of the Zika virus and microcephaly in South America. Active learning elements were designed using the Top Hat learning platform to be used in a large lecture class. The instructor presents case information and scientific data and the students engage with the material using facilitated discussion boards, online polling and multiple-choice questions. The case serves as a capstone to the course and requires the students to apply knowledge that they have acquired throughout the semester. Topics include cell transport and signaling, evolution and phylogenetic trees, central dogma of genetics, and patterns of inheritance and biotechnology. During the case study, the students see how the basic concepts of biology can be applied to solve real-world issues. Although this case was used in a majors introductory biology course as a capstone, it can also be used as a refresher at the beginning of multi-semester introductory biology courses and in upper-level health related biology courses with little modification.

P1-225 LEONARD, KL*; SANDMEIER, FC; TRACY , CR; WEITZMAN, CL; Colorado State University-Pueblo, University of Nevada, Reno, University of Nevada, Reno; *kendralleonard@gmail.com*

Coinfection of Pasteurella testudinis and Mycoplasma agassizii in the Mojave Desert tortoise (Gopherus agassizii)

Some species of *Pasteurella* are known to cause disease in vertebrates, often within the respiratory system, and in association with *Mycoplasma*. While *Mycoplasma agassizii* is a known etiologic agent of upper respiratory tract disease (URTD) in the Mojave Desert tortoise (*Gopherus agassizii*), the effect of *Pasteurella testudinis* on URTD in wild populations is not known. Understanding the dynamics of coinfection of *P. testudinis* and *M. agassizii* may allow for improvement in conservation efforts, especially regarding URTD management during necessary translocations. A hydrolysis probe (TaqMan) quantitative polymerase chain reaction (qPCR) for *P. testudinis* was developed to detect the presence or absence of *P. testudinis* in DNA extractions from tortoise lavage samples that were collected from tortoises (n = 389) in the Mojave Desert from 2010-2012. In 20 sampled populations, the prevalence of *P. testudinis* ranged from 0-100%, with a mean of 53% of individuals colonized with the microbe. Coinfection occurred at a low rate (103/389), and *P. testudinis* was not correlated to *M. agassizii* or URTD. While previous studies have found *P. testudinis* in association with disease, we found no indication that the presence of *P. testudinis* and coinfection of *P. testudinis* with *M. agassizii* worsens URTD in the Mojave Desert tortoise.

P2-211 LEPIANE, K/L*; CLARK, C/J; University of California, Riverside; *klepi001@ucr.edu*

The Effect of the Leading-edge Comb on Owl Flight Sounds

Owls have unique wing and feather characteristics that aid in silencing their flight. One example is the leading-edge comb, modified barbs that give the leading edge of the wing a serrated appearance. The leading-edge comb is hypothesized to reduce sound by modifying the airflow over the dorsal surface of the wing. One proposed function of the leading-edge comb is that it increases the angle of attack at which stall occurs, stabilizing owls at the high angles of attack which may occur during prey capture. An additional hypothesis is that the leading-edge comb reduces the sound produced during ordinary flight. To test this hypothesis, we placed the outermost flight feather (P 10) of the Barred owl (*Strix varia*) in an acoustic wind tunnel at a velocity of 8 m/s and a variety of angles of attack. We then experimentally manipulated the feathers by removing the leading-edge comb to test how sound production changes as a function of angle of attack. We recorded sound both in the near-field, in the approximate location of an owl's ear; and in the far-field. This enables us to test how the comb and angle of attack influence biologically-relevant aerodynamic sounds.

S4-9 LEPITO, Angela; DreamWorks Fearture Animation; *angela.lepito@dreamworks.com*

The Collaboration of Feature Animation and the Scientific Community

Most people associate animation with classic fairy tales, wily rabbits, and a square sponge. But animation is the collision of art and science. This intersection has long been the basis of a symbiosis between artists and scientists at DreamWorks Animation. How does an animation studio use scientific principles and engage in science education to make our films better? By facilitating scientific master-classes, demos and lectures we give our creators a fundamental understanding of reality that enables them to create the animation caricature known as the Illusion of Life. We leverage principles of biology and physics to create believable performances. I will share insights about our custom programming such as master-classes on Quadruped Anatomy and Flight and how these result in a better image on screen. Conversely, animators offer storytelling tools to the scientific community. Animators often use visualization tools similar to those that many scientists use, but in differing narrative orders and with budgets often far exceeding those of scientists. Thus they can offer new strategies of presentation and faster processes of development of those tools - enhancing understanding and increasing the speed of building bridges to share information with the public. This can help scientists leverage their own scientific principles as they present the importance and excitement of their work to the public, as well as to one another.

P1-136 LESTZ, L; BARNES, MS; POWERS, KG; LANGKILDE, T; BLACKBURN, DG*; Trinity College, Hartford, Pennsylvania State University; *daniel.blackburn@trincoll.edu*

Evolution of Yolk Processing in Reptiles: Evidence from the Lizard Sceloporus undulatus

Reptiles and birds are widely believed to share patterns of early development, including mechanisms of yolk cleavage and yolk cellularization. These patterns are widely assumed to have been retained from the common amniote ancestor. However, our observations on the lizard *Sceloporus undulatus* (Phrynosomatidae) have revealed a pattern of yolk processing that is very different from that of birds. Light microscopy and SEM show that as the endodermal cells proliferate, they form clumps of interconnected cells that are filled with yolk droplets. During vascularization, capillaries become encased in these cells, forming masses of elongated, spaghetti-like strands. As a result, the blood vessels are optimally -positioned to transport products of yolk digestion to the developing embryo. Recent studies in our lab have found that this unexpected pattern also occurs in snakes; therefore, it may be ancestral for squamate reptiles. The diversity of yolk processing mechanisms in sauropsids has significant implications for our understanding of the evolution of the amniote egg.

P2-54 LEUNG, N*; DE LEY, I; PAINE, T; University of California, Riverside; *nleun003@ucr.edu*

Molecular Barcoding and Pathogenicity of Unknown Phasmarhabditis (Nematoda) Species from Earthworms

Phasmarhabditis hermaphrodita is a parasitic nematode commercially available as a slug biopesticide (Nemaslug®) in 14 European countries and was recently discovered in California. Two undescribed isolates of *Phasmarhabditis*, EM434 and DF5056, were recovered separately from unknown earthworm species in New York. This study aimed to characterize these two isolates and determine their effects on a range of nontarget earthworm species. Both were characterized by sequencing the mitochondrial cytochrome c oxidase 1 gene (CO1) using primers CO1-F1 and CO1-R2. The CO1 is often used as the standard barcode for almost all animal groups. The COI of DF5056 (two females) and EM434 (four females) consisted of 658 identical base pairs, however, NCBI BLAST comparison revealed that these sequences are unique. Infectivity of EM434 and DF5056 was tested on three nontarget earthworm species *Eisenia hortensis*, *E. fetida*, and *Lumbricus terrestris*; and on invasive slugs: *Deroceras reticulatum* and *Lehmannia valentiana*, using the Nemaslug® recommended dose of 30IJ/sq cm and a higher dose of 150IJ/sq cm. Preliminary studies showed that EM434, at both rates, infected and caused mortality on susceptible *D. reticulatum* and *L. valentiana*, but not on the three earthworm species tested. The same tests were repeated using DF5056, resulting in the mortality of two non-target earthworm species, *Eisenia hortensis* and *E. fetida*, and the two slug species. Preliminary results suggest DF5056 is more virulent than EM434.

119-2 LEVELL, ST*; REZNICK, DN; Univ. of California, Riverside; *sleve004@ucr.edu*

Intergenomic Conflict: Understanding Maternal Investment and Post-Zygotic Mate Choice

Placentas are well-known reproductive organs used to nourish offspring in-utero. Species in the livebearing fish family Poeciliidae have evolved placentas multiple times throughout evolutionary history. The presence or absence of a placenta allows us to experimentally assess the biological consequences of having a placenta. Specifically, parent-offspring conflict is a predicted consequence of the inequalities between the quantity of resources in the best interest of mother to provide her offspring and the somewhat larger quantity that are in the best interest of offspring to get from their mother. This conflict is exaggerated if females mate with multiple males. Mothers in species that lack placentas fully provision eggs before fertilization. Parent-offspring conflict is predicted to be low because offspring cannot garner more resources from their mother than mothers provided before the egg was fertilized. Species with placentas are predicted to have high levels of conflict because mothers continue to supply nutrients throughout gestation This project investigates parent-offspring conflict and genomic conflict between parents' in a placental fish, *Poeciliopsis prolifica*. Conflict theory predicts that there will be a reconciliation of conflict within populations but differences among populations in how conflict is resolved. If so, females may be able to recognize and differentially allocate resources to offspring sired by males from her own population. Females were artificially inseminated with sperm from males in their own population and a different population. Resulting paternity and offspring size were recorded to gauge post-copulatory female preference. This project tells us how females allocate resources based on the male they are mating with, both in fertilizing eggs and in providing nutrients to their offspring.

35-8 LEVESQUE, D.L.; University of Maine; *danielle.l.levesque@maine.edu*

Tropical thermoregulatory phenotypes: insights into the relationship between basal metabolism and energetic outputs in mammals

Despite a large body of knowledge on the thermoregulation of temperate and cold-climate endotherms, our functional knowledge of endotherms in warmer climates remains incredibly scarce. In particular, their use of facultative heterothermy, lowering or raising body temperatures to conserve energy and/or water, has been chronically understudied. Small endotherms (<5kg) are often assumed to live predominantly at temperatures below thermoneutrality. Tropical and subtropical mammals, however, routinely experience temperatures above the lower critical limit of their thermoneutral zones. Therefore, unlike temperate species that must consistently generate heat to maintain an elevated body temperature, low latitude species spend more time at thermoneutrality and therefore can spend the energy elsewhere. As well as providing a general overview of some of the forms of heterothermy observed in warm climates, I will review the results of field studies on a highly heterothermic nocturnal mammal (the greater hedgehog tenrec, *Setifer setosus*) and a homeothermic (yet thermally labile) diurnal mammal (the large treeshrew, *Tupaia tana*). I discuss the costs and benefits of the body temperature variability in warm climates, the evolution of homeothermy in mammals, and the links (or lack thereof) between basal metabolic rates and life histories in mammals.

17-6 LEVIN, E*; LOPEZ-MARTINEZ, G; FANE, B; DAVIDOWITZ, G; Tel-Aviv University, Israel, New Mexico State University, Las Cruces, University of Arizona, Tucson, University of Arizona, Tucson; *levineran1@gmail.com*

Nectarivores Use Sugar to Reduce Oxidative Damage From Flight

Many species of birds, butterflies, and moths fly hundreds and even thousands of miles and feed almost exclusively on nectar. Migratory and hovering flight are energetically demanding and result in high levels of oxidative damage. How nectar feeding animals mitigate this damage is not well known. In this study, we show that the Carolina Sphinx Moth (*Manduca sexta*), a model nectarivores, shunts glucose from nectar to the pentose phosphate pathway (PPP); this produces the antioxidant potential as NADPH and reduced glutathione, which are used to reduce oxidative damage to muscle cell membranes due to the intense flight. We propose that consumption of carbohydrate-rich nectar, the intense demands of flight, and the use of the PPP are causally linked and that this linkage has enabled the evolution of nectarivores' extreme metabolically demanding modes of locomotion, including hovering and migratory flight. This linkage also has broader implications as it may explain how other organisms that feed on carbohydrate-rich foods can minimize oxidative damage due to high aerobic metabolic activity

101-5 LEVIN, I I*; FOSDICK, B K; TSUNEKAGE, T; ABERLE, M A; BERGEON-BURNS, C M; HUND, A K; SAFRAN, R J; Agnes Scott College, Colorado State University, Virginia Polytechnic Institute and State University, Indiana University, University of Colorado; *ilevin@agnesscott.edu*

Demonstrating causality among features of the integrated phenotype: changes in social interactivity and hormones are associated with experimental manipulation of a signal trait

Morphological and physiological traits are often predictive of reproductive performance, and researchers make inferences about how behavior operates to shape those relationships. However, it is rare that we understand exactly how those traits translate to reproductive success, as this involves detailed information about individual behavior, and its physiological basis, that can be difficult to obtain. We deployed proximity loggers on breeding barn swallows (*Hirundo rustica erythrogaster*) to test how experimentally manipulating male ventral plumage color affects social interactivity, reproductive success, and aspects of physiology including testosterone and stress-induced corticosterone. First clutch eggs were collected for a record of paternity pre-manipulation and adult swallows were tagged with Encounternet proximity loggers. Tags recorded close proximity interactions for two days both before and after half of the males in the network had their ventral plumage experimentally darkened. Physiological data were collected pre- and post-manipulation for nearly all individuals. Two years of experimental data show that a male's social interactivity changed proportionally to his change in plumage color. Males who experienced a greater shift in color (pale to dark), a larger, positive change in testosterone levels, and a dampened stress-induced corticosterone response had a larger, positive change in the number of interactions with their social mate post-manipulation compared to pre-manipulation. Changes in male-male interactions were not directly related to the phenotype manipulation or changes in physiology.

P3-61 LEVITAN, BB*; GÓMEZ-JIMÉNEZ, S; LI, J; KÜLTZ, D; Univ. of California, Davis, Centro de Investigación en Alimentación y Desarrollo (CIAD); *bblevitan@ucdavis.edu*

Unique Proteome Dynamics in Livers of a Warm-adapted Population of Threespine Sticklebacks

This study investigated the molecular phenotypes of a warm-adapted population of a typically cold-adapted species. A unique population of threespine sticklebacks (*Gasterosteus aculeatus*) from Baja California, Mexico (LaBoRo) are surviving and breeding at temperatures near 30 degrees Celsius, a temperature that is close to the upper thermal limit for this species. Understanding how this warm-adapted population functions at high temperatures at the molecular level may give insight into the mechanisms that have allowed for their survival and the potential for other populations to adapt to increasing temperatures. We created a spectral library for the livers of four populations of threespine sticklebacks (N=24), using data dependent acquisition (DDA) proteomics. The spectral library was used to set up a validated target list of proteins that were then quantified using data-independent acquisition (DIA) quantitative proteomics. LaBoRo livers were compared using DIA quantitative proteomics to those of three cold-adapted populations: a resident marine population (Bodega Harbor, CA), a freshwater population (Lake Solano, CA), and an anadromous population (Anchorage, AK). Four separate comparisons between six LaBoRo threespine sticklebacks and six fish from each of the other three groups were made and population-specific protein expression patterns identified (N=96). This study highlights liver proteins that are consistently found at higher abundance in the LaBoRo population and thus may be important for heat adaptation. Our study lays the groundwork for highly accurate quantification of proteome-wide *G. aculeatus* liver protein differences by DIA quantitative proteomics. Funded by NSF Grant IOS-1355098.

P1-224 LEVORSE, A.*; CHARLES, K.; ROSA, G.M.; GRAYSON, K.; VOYLES, J.; University of Richmond, University of Nevada, Reno; *andrew.levorse@richmond.edu*

Interactions between Two Key Amphibian Defenses to Batrachochytrium dendrobatidis in Panamanian Glass Frogs (Espadarana prosoblepon)

Research on the amphibian pathogen Batrachochytrium dendrobatidis (Bd), the causative agent of the lethal disease chytridiomycosis, has shifted from assessments of pathogenicity and susceptible species to more specialized questions concerning the complex interactions between the pathogen, species-specific immune responses, and the environment. Our work examines the potential for interactions between two innate immune defenses of frogs against Bd: 1) secretions of antimicrobial peptides and 2) communities of commensal cutaneous bacteria. While both defenses have been studied individually, little data are available to examine interactions between these defenses. We caught Panamanian glass frogs (Espadarana prosoblepon) and stimulated them to release skin secretions, which we quantified with a protein assay. We also collected samples of cutaneous bacteria before and after stimulation to determine if the bacterial community changed after skin secretion. We used the bacteria samples to isolate and purify unique bacterial types based on colony morphology, then used challenge assays to understand the impact of isolated bacterial types on Bd growth in vitro. These data, in conjunction with the abundance of each bacterial type before and after the frogs secreted antimicrobial peptides, are useful to understand the interactions of the defenses. By examining whether the interactions of these independent defenses are additive or antagonistic, and their ultimate consequence for amphibian susceptibility to Chytridiomycosis, our research can aid conservationists in determining the best course of action in the management of amphibian disease.

115-1 LEWIS, AK*; COHN, MJ; University of Florida; *lewis23a@ufl.edu*

Structural defects of the external genitalia induced by the environmental fungicide vinclozolin

In recent decades, there has been a rise of endocrine-related diseases and disorders, including an increased incidence of genital malformations, low semen quality, adverse pregnancy outcomes, neurobehavioral disruption, endocrine-related cancers, earlier onset of breast development, obesity, and type 2 diabetes. An example of increased genital malformations is seen with congenital penile anomaly (CPA) frequency, which has increased to a rate of 1 in 125, or 0.83%, of male newborns. The most commonly reported CPA is hypospadias, which accounts for 68.3% of CPAs. Hypospadias is characterized by an atypical urethral opening along the penile shaft, within the scrotum, or in the perineum. Chordee, or penile curvature, accounts for 8.6% of CPAs, while hypospadias plus chordee make up 5% of CPAs. Chordee without hypospadias is a congenital anomaly that usually results in a ventrally tethered penis and normally positioned urethral opening. We found that male mouse embryos exposed to the endocrine disruptor vinclozolin develop external genital defects that mimic human congenital penile anomalies. Female mouse embryos exposed to vinclozolin also develop external genital defects. We have investigated the molecular mediators vinclozolin-induced genital defects and find that these malformations result from disruption of the activity of genes that normally pattern the genital tubercle.

S1-6 LEYS, SP*; KAHN, AS; YAHEL, G; BANNISTER, RJ; Univ. of Alberta, Ruppin Academic Center, Institute of Marine Research; *sleys@ualberta.ca*

Oxygen requirements of sponges and the origin of multicellular animals

The appearance of multicellular animals during the late Proterozoic Era is thought to have coincided with oxygenation of the oceans, however we know little about the oxygen needs of early animals. Extant sponges are our best modern links to the theoretical bacterivorous, filter-feeding ancestors of animals. The apparent simplicity of the sponge body plan commonly leads to the assumption they are readily ventilated and have a low oxygen demand. However recent data suggest that resistance through the sponge can make filtration cost up to 30% of metabolism. To understand how modern sponges cope with the costs of filtration we studied the metabolism of two groups of deep water sponges in situ and in tanks. Glass sponges have thin tissues and large canals that are highly adapted to use induced current to reduce their costs of pumping. Whereas the glass sponge *Aphrocallistes vastus* removes only 0.5-2 µM of dissolved oxygen from the water it filters, in contrast, with dense tissues packed with microbes and narrow canals, the HMA demosponge *Geodia barretti* removes 20-40 µM of dissolved oxygen from the water it filters, presumably due to efficient metabolism of DOM by its symbionts. We used flow-through chambers to determine how tolerant *G. barretti* might be to hypoxic conditions. *G. barretti* quickly becomes anoxic if pumping ceases. The sponges continued to filter, though at a reduced rate, at 40 µM ambient oxygen (14% present atmospheric levels, PAL) and ceased pumping at 4-7% PAL. Recovery was rapid even after 48 hours in 20 µM (7% PAL) oxygen. While some sponges tolerate periods of hypoxia, normal feeding is energetically expensive. If the first multicellular animals were filter feeders then oxygen availability could have been a driver for the evolution of early body plans.

13-8 LI, DH*; GILLY, WF; Hopkins Marine Station of Stanford University; *lidh@stanford.edu*

Recovery of giant-axon-mediated escape jetting after exposure to severe hypoxia in Doryteuthis opalescens (California market squid)

Squids display a wide range of swimming behaviors including the powerful escape jet mediated by the giant and non-giant axon systems, which can act individually or in concert. Due to the squid's high oxygen demand to sustain muscular activity, maintaining essential behaviors against environmental variation poses a major challenge. *Doryteuthis opalescens* found in Monterey Bay, CA often encounters cold, hypoxic water from offshore, but the effects of hypoxia on locomotion and its underlying mechanisms have remained unexplored. We recorded stellar nerve activity and simultaneous pressure inside the mantle cavity of escape jets elicited in *D. opalescens* (N=16). Squid were exposed to a dissolved oxygen ramp at 8°C from normoxia (8 mg/L) to hypoxia (0.5 mg/L) and back to normoxia, spending up to 1 hour (LT50) at 0.5 mg/L. Nine squid produced giant-axon-mediated escape jets during the whole experiment including the hour at 0.5 mg/L. In the other seven squid, the giant axon system and subsequent jetting failed after an average of 23.1 minutes (range 5-39 min) at 0.5 mg/L. Four squid recovered upon return to normoxia whereas three died. Across all squid, jets elicited under hypoxia had smaller peak pressure, longer latency, and reduced giant axon activity than those in initial normoxic conditions. Jets from squid that recovered in final normoxic conditions had larger peak pressure and shorter latency than those in hypoxia but were still hindered when compared to initial conditions. Our results suggest that exposure to hypoxia affects locomotor performance in *D. opalescens* by impairing giant axon activity, though the ability to recover shows inter-individual variation.

124-4 LI, Y*; HALANYCH, KM; Auburn University; *yzl0084@auburn.edu*

Comparative genomics of seep-dwelling tubeworm (Siboglinidae: Annelida) endosymbionts

The evolution of gutless siboglinids, which are important members of chemosynthetic communities, has been hypothesized to be driven by preference for reducing habitats and their dependence on endosymbionts. However, genomes from only a few vent-dwelling vestimentiferan and bone-eating Osedax symbiont genomes have been sequenced and characterized. Here we focus on the genomes of gamma proteobacteria symbionts from vestimentiferan and frenulate siboglinids. Vestimentiferans tend to grow to relatively large sizes whereas frenulates are typically more diminutive. To understand differences in these holobiont systems, we sequenced 3 vestimentiferan and 1 frenulate symbiont genomes collected at hydrocarbon seeps and compared them to endosymbiont genomes from hydrothermal vent regions. All sampled endosymbionts from seep-dwelling siboglinids are also able to use rTCA cycle in addition to Calven-Benson cycle for carbon fixation. However, representative of frenulates, the Galathealinum symbionts lack key enzymes associated with rTCA and can only use Calvin cycle for carbon fixation. Thus, we hypothesize that symbionts with higher metabolic flexibility in carbon fixation may allow tubeworms to thrive in more reducing environments, such as seeps and vents. In addition, we show that metabolisms of sulfur, nitrogen are largely conserved across all siboglinid chemoautotrophic symbionts. Surprisingly, we find that the ability to use hydrogen as an additional energy source is probably also widespread in cold seeps than previous recognized, especially for siboglinid symbionts. Lastly, we take a comparative approach to systematically characterize the molecular mechanisms related to the process of infection. These results suggest that there are previously unrecognized links among siboglinid symbionts from different deep-sea chemosynthetic environments and shed light on understanding of evolutionary trends of siboglinid host-symbiont evolution.

47-5 LI, J*; LEVITAN, BB; GÓMEZ-JIMINÉZ, S; KÜLTZ, D; Univ. of California, Davis, Centro de Investigación en Alimentación y Desarrollo (CIAD); *joli@ucdavis.edu*

Ecological proteomics of three-spine sticklebacks (Gasterosteus aculeatus) with a standardized gill DIA assay

The three-spine stickleback *(Gasterosteus aculeatus)* is a euryhaline teleost that is represented by ancestrally marine populations and has invaded freshwater (FW) habitats since the Pleistocene glacier retreat. Sticklebacks are a suitable candidate for comparative studies due to their global distribution in marine, brackish and FW habitats throughout the northern hemisphere. A standardized data-independent acquisition (DIA) assay for label-free quantitative proteomics of 1505 proteins has been established for three-spine stickleback gills. Spectral libraries created by data-dependent acquisition (DDA) and annotated using multiple search engines were used for DIA assay construction. Skyline and a sample training set were used for automated and manual assay curation to select and validate reproducible transitions for protein quantitation. The resulting gill DIA assay yielded 1505 proteins represented by at least 4 transitions for at least 2 proteotypic peptides per protein. This gill DIA assay identified and quantified gill proteins with unique population-specific abundances between stickleback populations from Lake Solano, CA, resident marine from Bodega Harbor, CA, cold-adapted anadromous from Westchester Lagoon, AK, and warm adapted from La Bocana del Rosario, MX. Curated DIA assays permit comprehensive quantitative assessment of previously unknown biological adaptations associated with specific ecological contexts. The consistent, standardized, and high-throughput nature of curated DIA assays empowers future network approaches for capturing proteome dynamics in diverse ecological contexts. Funded by NSF Grant IOS-1355098

S8-11 LI, Yi; TAN, Xiaodong; TANG, Jie; BEISEL, Kirk W.; LOVAS, Sandor; HE, David Z*; Beijing Tongren Hospital, Creighton University; *hed@creighton.edu*

Evolutionary Insight Into Functional and Structural Changes of Prestin, the Motor Protein of Cochlear Outer Hair Cells

Prestin is the 5th member of an eleven-member membrane transporter superfamily of SLC26A proteins. Prestin primarily functions as a motor protein with unique capability of performing direct and reciprocal electromechanical conversion on microsecond time scale. Prestin-based outer hair cell motility is responsible for the exquisite sensitivity and frequency selectivity seen in the mammalian cochlea. Although prestin is also expressed in the zebrafish, amphibian, and reptilian hair cells, it functions as an ion transporter. During evolution, the ion transport capability, typical of SLC26A members, was replaced by an innovation that is unique to the therian OHCs with a voltage dependent motility. In this presentation, we will review recent work from comparative, evolutionary studies using site-mutagenesis, domain swapping and voltage-clamp techniques. On the basis of our new studies using a combination of ab initio structure prediction, 3D folding recognition by threading, homology modeling, molecular dynamics simulations and site-mutagenesis, we propose a new mechanism of how prestin interacts with intracellular anions to generate gating current and conformational change. Future research directions and potential application of prestin will also be discussed (Supported by NIH grant R01 DC 004696 from the NIDCD).

22-5 LIAO, JC*; AKANYETI, O; PUTNEY, J; YANAGITSURU, YR; LAUDER, GV; STEWART, WS; Univ. of Florida, The Whitney Laboratory for Marine Bioscience, St. Augustine, Aberystwyth University, Wales , Georgia Institute of Technology, Atlanta, UC Davis, Davis, Harvard University, Cambridge, Eastern Florida State College, Melbourne; *jliao@whitney.ufl.edu*

Acceleration in fishes; a multi-species comparison reveals a common hydrodynamic mechanism

The ability to move is one the key evolutionary events that led to the complexity of vertebrate life. The most speciose group of extant vertebrates, fishes, has been documented to display a remarkable diversity of movement patterns during steady swimming. Much less attention has been paid to forward acceleration, despite its potentially larger role in prey capture and predator evasion. We discovered that for the 51 species we studied, this behavioral diversity collapses into one locomotor strategy when fishes are challenged to accelerate, regardless of their body size, shape or ecology. Employing flow visualization and biomimetic models, we provide evidence that accelerating fishes increase their propulsive efficiency by altering vortex ring geometry. Our study demonstrates a fundamental difference between steady swimming and acceleration and suggests a unifying hydrodynamic principle based on a symmetrical wake morphology that is likely conserved across all aquatic undulatory vertebrates.

135-6 LIBBY, T*; CHUKWUEKE, C; SPONBERG, S; University of Washington, Georgia Institute of Technology; *tlibby@berkeley.edu*

Load-dependent muscle work tunes perturbation response with changing running frequency.

Muscle's intrinsic properties can stabilize movement through the length- and velocity-dependence encompassed in Hill-like models, but these models fail to predict history-dependent effects which may play a larger role in function during perturbed or unsteady locomotion. We examined whether muscle function varied during identical rapid perturbations occurring at different frequencies of movement. We modified the workloop approach to incorporate perturbations and replicated unsteady conditions in a fast-running cockroach, *Blaberus discoidalis*. Prior to perturbation, we imposed length oscillations consistent with running kinematics across the natural speed range (1-20 Hz). We imposed rapid stretch perturbations (1/10th preferred stride period, 6% muscle length) against this varying time-history of movement. The muscle experienced the same kinematics and stimulation during all perturbations, thereby isolating the effect of history. The Hill model would predict identical perturbation responses across all conditions. By contrast, we found that the energy dissipated by the muscle during these identical perturbations varied almost 10-fold across cycle frequencies. While muscle behavior appeared viscoelastic during the stretch, we did not observe a consistent relationship between force history and muscle stiffness. Instead, we found a shift in force offset during the perturbation that correlated strongly to muscle force during the cyclic history prior to the stretch. The effects are partly explained by adding a series elastic element to the Hill model. Our results suggest that as muscle force varies across behavioral context (e.g. from slow to fast running), perturbations are met with a mechanical response that matches the motor load.

15-1 LICHTENSTEIN, J.L.L.*; WRIGHT, C.M.; MCEWEN, B.; PINTER-WOLMAN, N.; PRUITT, J.P.; LICHTENSTEIN, James; University of California Santa Barbara, University of Pittsburgh, University of California Los Angeles; *jlllichtenstein@gmail.com*

The multidimensional behavioural hypervolumes of two interacting species predict their space use and survival

Individual animals differ consistently in their behaviour, thus impacting a wide variety of ecological outcomes. Recent advances in animal personality research have established the ecological importance of the multidimensional behavioural volume occupied by individuals and by multispecies communities. Here, we examine the degree to which the multidimensional behavioural volume of a group predicts the outcome of both intra- and interspecific interactions. In particular, we test the hypothesis that a population of conspecifics will experience low intraspecific competition when the population occupies a large volume in behavioural space. We further hypothesize that populations of interacting species will exhibit greater interspecific competition when one or both species occupy large volumes in behavioural space. We evaluate these hypotheses by studying groups of katydids (Scudderia nymphs) and froghoppers (Philaenus spumarius), which compete for food and space on their shared host plant, Solidago canadensis. The data discussed herein clarify the role that personality can play in species interaction at the scale of small to large groups. Therefore, this study serves as a stepping stone towards elucidating the role of animal personality in ecological processes at the scale of populations and communities.

P3-100 LIGOCKI, IY*; FARRAR, V; MUNSON, A; VIERNES, RC; CONNON, RE; SIH, A; CALISI, RM; UC Davis; *iyligocki@ucdavis.edu*

Reproductive consequences of a changing world: effects of the pesticide bifenthrin on mosquitofish reproductive behavior

In recent decades, pyrethroid pesticides have been deemed as a safer alternative to previously used organophosphate pesticides in agricultural and urban settings. While some evidence supports this in mammals and birds, little is known of their nonlethal effects in fish. A large percentage of urban and agricultural runoff enters waterways that contain fish and other organisms of great environmental and economic value; understanding the nonlethal effects of emerging pollutants on organisms in these systems could prove critical to preserving these resources. In fish, exposure to certain pyrethroids can affect concentrations of hormones vital to reproduction. Thus, we hypothesized that pyrethroid exposure impacts reproductive behavior. We tested our hypothesis by examining the effects of the widely used pyrethroid pesticide, bifenthrin, on the reproductive behaviors of the broadly distributed livebearing western mosquitofish, *Gambusia affinis*. We exposed adult female fish to one of five ecologically relevant concentrations of bifenthrin for 14 days and conducted behavioral assays before and after exposure. Compared to pre-exposure and controls, low levels of bifenthrin exposure were not significantly associated with mate choice and sociality behavior. We will therefore present data that determine the impacts of bifenthrin exposure on transcriptional responses relating to reproductive and stress-related genes in brain and liver, along with behavioral scores and space use. In addition, we will highlight the importance of focused studies needed to investigate downstream effects of exposure on development and reproduction in both acutely and chronically exposed populations.

16-1 LIGOCKI, IY*; EARLEY, RL; HAMILTON, IM; UC Davis, U of Alabama, Ohio State U; *iyligocki@ucdavis.edu*

Sex- and threat-based responses to territorial intruders in a social fish

Territorial defense is beneficial to social animals, however individuals within groups may differ in their participation in defense. This could be a consequence of variation in individual ability to provide defense, the relative benefits of providing defense, or the costs associated with particular types of intruders. Further, "powerful" members of groups may be able to influence other group members to modify their response to intruders in such a way to reflect the fitness interests of powerful individuals. We hypothesized that the size and relative size of dominant breeding pairs *Neolamprologus pulcher* would influence 1) their ability to defend against perceived intruders of the group, and 2) their ability to influence the behavioral response of other group members to intruders. We also hypothesized that size (and relative size) of group members would influence the baseline cortisol levels of individual *N. pulcher*. To test these hypotheses, we exposed successfully breeding pairs of *N. pulcher* to three types of intruders, and measured cortisol levels in each fish one week after behavioral trials were complete. Pairs consisted of fish which varied in relative size. Compared to groups in which males were much larger than females, males performed fewer aggressive acts and females performed more aggressive acts towards intruders when males and females were similar in size. Male and female *N. pulcher* responded less aggressively towards a heterospecific fry predators than they did towards unfamiliar conspecific *N. pulcher*. There was not a significant relationship between individual cortisol levels and the size (or relative size) of pairs of *N. pulcher*, or behavioral interactions within the dyad. We conclude that individual phenotype, as well as the interacting phenotypes in groups, can have important consequences for the social dynamics in animal groups.

55-6 LIGUORI, AL; Stony Brook University;
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Population level differences in life history responses to long-term pH stress in Tigriopus californicus

Due to unprecedented increases in atmospheric CO_2, marine organisms now face a rapid global reduction of seawater pH, or ocean acidification (OA). To date, the majority of studies on biological responses to OA are short-term and the potential for acclimation and adaptation is rarely addressed. I performed experiments on the model copepod *Tigriopus californicus* to investigate population level differences in the effect of pH on life history across multiple generations. Reproductive F0 females from each of 4 geographically isolated populations were allocated to 3 pH treatments: 8, 7.5, and 7. Cultures were maintained in these treatments through the F3 generation. For each generation and population, I quantified survivorship, fecundity, and development time. Initial nauplii production by F0 females was not affected by pH, however, there were large differences in fecundity among populations. Later in F1 development, population sizes and development rates were reduced in the 8 pH, for all populations. After F1 adults were isolated to start the F2 generation, copepods in the 8 pH initially produced the most nauplii. However, by week 4 of F2 development, population sizes in the 7.5 and 8 pH treatments dropped drastically, leaving few F2 adults to begin the F3 generation (experiments on survivors are ongoing). These results suggest that transitions through later developmental stages may be most sensitive to different pH treatments. There were population differences in life history throughout the F2 generation, but all populations had highest overall performance in the 7 pH. *T. californicus* inhabits tidepools, which undergo large diurnal and seasonal fluctuations in pH. This species may be preadapted to low pH conditions and may tolerate higher pH, but only for short-term exposure. Coastal species that currently experience extreme abiotic variability may be resilient to rapid environmental change.

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Leg spring stiffness varies with foot strike pattern and shoe type during running in humans

The spring-mass model for running predicts the leg mechanics of animals during running (Farley et al., 1993). As surface stiffness increases, leg spring stiffness (k_{leg}) of a runner decreases to maintain a constant total stiffness (Ferris et al., 1998), suggesting that different shoes can influence leg stiffness. We hypothesized that runners who forefoot strike (FFS) and are barefoot run with stiffer legs. Healthy runners (N = 21) ran along a 19.8-m runway under four conditions: barefoot, minimalist shoe (Nike Free), traditional shoe (Asics cumulus), and maximalist shoe (Hoka Bondi). We measured foot strike angle using a camera (208 fps), joint kinematics using a motion capture system (220 fps), and 3D ground reaction forces with a force platform (625 Hz). Leg spring stiffness was calculated using three models: (A) slope of the work-loop, (B) peak force divided by peak leg compression, and (C) Farley's model (1993). With model (A), runners who FFS ran with 23% stiffer legs than those who rearfoot strike (RFS; $p<0.05$; 3-way ANOVA; R). By contrast, with models (B) and (C), runners who FFS ran with 11% and 21% more compliant legs, respectively, compared with RFS runners. Regardless of model, FFS runners had different leg spring stiffnesses than RFS runners ($p<0.05$). The three models led to very different outcomes, where (B) resulted in the highest leg stiffnesses and model (C) in the lowest leg stiffnesses. With (A) and (B), barefoot runners stiffened their legs ~30% more than when wearing maximalist shoes. However, with model (C), runners in minimalist shoes had the stiffest legs. Regardless of model, runners adjusted the muscle-tendon-ligament systems of their legs to store elastic energy depending on footstrike pattern and shoe type.

P2-152 LINDSAY, S*; DEON, H; HOLMES, S; MILLER, E; SILVERBRAND, S; RAWSON, P; University of Maine, Orono;
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Surveying Benthic Invertebrate Communities Associated with Oyster Aquaculture Sites in Maine

Compared to finfish aquaculture, shellfish aquaculture is predicted to have less impact on benthic communities because organic enrichment and biodeposition rates are typically lower, but impacts are likely to vary with species cultured, site characteristics, and farming methods. Oyster aquaculture is a growing industry in Maine and little is known about its impacts on the benthos. We surveyed benthic biodiversity under and adjacent to suspended oyster cages at three farms on different rivers in Maine during 2015 and 2016. We collected sediment using ponar grabs, sieved it (0.5 mm mesh) and preserved all retained material for later identification. Approximately 6000 individual invertebrates were sorted and identified to the lowest taxonomic level possible (i.e., species, genus or family). Annelids and molluscs were the most abundant fauna at all three farms. Taxonomic similarity (percentage similarity) of fauna collected under and adjacent to oyster cages differed by farm, ranging from ~43% to 79%. At two farms, Capitellid polychaetes and Oligochaetes were most abundant under cages (dominance index=0.3-0.4), while Veneriid bivalves, Nereidid and Spionid polychaetes were most abundant in samples taken adjacent to cages at the same farms (dominance index=0.2-0.4). *Streblospio benedicti* (Spionidae) was the most abundant taxon at the third farm, regardless of sample location in the farm (dominance index ~0.8). Sediment organic content was slightly enriched under cages at only one site (12% vs. 10% organic carbon). Our data suggest that the oyster farms are having relative minor impacts on the benthic community at these sites. This material is based on work supported by the National Science Foundation under Grant No. 1355457.

20-5 LINS, LSF*; HELOU, L; FISTON-LAVIER, AS; KELLEY, J; LINS, Luana; Washington State University, Pullman, University of Montpellier; *luana.lins@wsu.edu*

Evolutionary Dynamics of the Antifreeze Protein III Gene Cluster in Polar Fish

Organisms living in polar environments are exposed to constant cold temperatures and long periods of darkness. Many species in polar regions experience temperatures that are below their serum freezing point and have independently evolved antifreeze proteins (AFPs). AFPs bind to forming ice crystals and inhibit ice recrystallization, which confers an adaptive advantage to the species that have AFPs. A recent study of the type III AFP gene in the Antarctic fish, *Lycodichthys dearborni*, showed that the *AFP* gene arose from the translocation and duplication of another gene (SAS-B). Tandem duplications of the new AFP gene led to a cluster of *AFP III* genes. A transposable element (TE) is located upstream of the *SAS-B* and the *AFP* cluster, suggesting the putative role of this TE in the formation of the AFP gene cluster. In this study, we aim to understand how this important protein (AFP) has evolved in some polar species and whether TEs are involved in this evolutionary process. To answer these questions, we characterized the *AFP* gene cluster region and analyzed the TEs density in *L. dearborni*. We identified a highly abundant TE in the AFP cluster that has not been identified for this species before: the L2-1 element. The L2-1 elements are located downstream of each annotated repeat unit of the *AFP III* gene with a conserved distance suggesting recurrent duplication events. We then further characterized the *AFP III* genes by examining the relationships among the gene copies and their nearby TE insertions. This analysis should allow dating the duplication events and testing whether TE insertions are involved in the duplication events. This study sheds light on the role of TEs in the evolution and duplication of novel proteins.

66-2 LIOTTA, MN*; ABBOTT, JK; RIOS-CARDENAS, O; MORRIS, MR; Ohio University, Lund University, Sweden, Instituto de Ecologia, Veracruz, Mexico; *ml996913@ohio.edu*

Tactical Dimorphism as a Potential Indicator of Intralocus Tactical Conflict in the Swordtail Xiphophorus multilineatus

Alternative Reproductive Tactics (ARTs) are discrete variations in the reproductive phenotypes of members of the same sex within a species. When shared traits between ARTs have a common genetic basis, but different fitness optima, the resulting antagonistic selection can generate Intralocus Tactical Conflict (IATC). Studies on IATC can greatly improve our understanding of how ARTs evolve. The evolution of tactical dimorphism is one of the mechanisms that can resolve IATC, and can also be used as an indicator for traits experiencing disruptive selection. Using the two male ARTs in the high-backed pygmy swordtail fish, *Xiphophorus multilineatus*, we employed geometric morphometrics to examine the extent of body shape dimorphism between the tactics. Courter males, that use only courtship to attract females, were significantly less dorsal-ventrally compressed than sneaker males, that alternate between courtship displays and forced copulation. Sneaker males switch from courtship to forced copulation in the presence of a competitor, but will engage in both behaviors even when alone with a female. Therefore, we also investigated if a sneaker male's morphology predicts the mating behavior it will most likely use in the absence of a competitor. Sneakers with a narrower body shape were more likely to use force copulatory behavior when alone with a female, suggesting that this may be the optimal morphology for this behavior. Future work will investigate the criteria necessary to demonstrate IATC in *Xiphophorus mulitlineatus*: shared traits are genetically correlated, opposing phenotypic optima for those traits, and that the tactics are currently not at their optima for those traits.

P1-238 LIPINSKI, A.R.*; FONTAINE, J.J.; BACHMAN, G.C.; NE Cooperative Fish & Wildlife Research Unit, Univ. of Nebraska-Lincoln, USGS Nebraska Cooperative Fish & Wildlife Research Unit, Univ. of Nebraska-Lincoln, Univ. of Nebraska-Lincoln; *alipinski2@unl.edu*

The Influence of Environmental and Physiological Interplay on the Condition and Movement Behavior of Subpopulations Under Unpredictable Climatic Conditions

External environmental conditions and organism physiology often influence one another in an iterative cycle that can have substantial effects on the behavior and fitness of individuals and groups of individuals. We aimed to examine relationships between the environment and the physiology of organisms within that environment to assess ultimate and proximate factors determining observed differences in behavior and fitness. We used northern bobwhite *(Colinus virginianus)* in Nebraska as a study system due to the highly variable climate and land use context found in the state and the organization of quail in winter social groups (coveys), allowing for examination of individual and subpopulation responses to environmental stimuli. We marked 18 coveys with VHF radio-collars and tracked covey movements from January 2017 to June 2017, as well as assessed body condition, baseline corticosterone levels, and survival. Preliminary results suggest that environmental context is correlated with variation in individual and subpopulation physiology and movement behavior. Observed variation in physical condition and behavior can have far-reaching effects on subpopulation persistence and broader population dynamics.

P1-106 LIPOWSKA, MM*; WYSZKOWSKA, J; SADOWSKA, ET; KOTEJA, P; Institute of Environmental Sciences, Jagiellonian Univ., Krakow, Poland; *malgorzata.lipowska@doctoral.uj.edu.pl*

Experimental Evolution of Stress Response: Changes in Corticosterone Level in Response to Chronic Mild Stress and Thermoregulatory Burden in Bank Voles from a Selection Experiment

The activity of a hypothalamus-pituitary-adrenal (HPA) axis is regulated by a conflict between beneficial and harmful actions of its main effector hormones, including corticosterone (CORT). A strong increase of blood CORT is beneficial when overcoming short, intense challenges, but can be harmful when the HPA axis remains stimulated for a long time. Therefore, adjustments of the HPA axis activity may participate in evolution of adaptation to certain challenges. Experimental evolution offers an efficient tool to approach the problem. We asked whether the HPA axis activity differs between lines of bank voles (*Myodes glareolus*) selected in three directions: high aerobic exercise metabolism (A), predatory behavior (P), ability to cope with low-quality herbivorous diet (H), and unselected control lines (C). We measured baseline CORT in blood of animals from three groups: challenged with chronic mild stress (CMS), challenged with increased metabolic demands of thermoregulation, and non-challenged. The thermoregulatory burden increased baseline CORT, but the effect did not differ among the selection directions. The response to CMS was altered by selection: baseline CORT increased in A and P lines, but remained unchanged in C and H lines. In conclusion, adaptation to challenges requiring burst activity of the HPA axis or its high sensitivity to stimuli can result in a higher susceptibility to chronic stress.

P1-175 LITLE , JW*; PIRES, A; PECHENIK, JA; LITLE, Jack; Pomona College, Dickinson College, Tufts University; *john.litle@pomona.edu*

Effects of Altered pH on Juvenile Feeding Rates in the Marine Gastropod Crepidula fornicata

Today's ocean surface is subject to increasing atmospheric carbon dioxide concentration, which lowers ocean pH and carbonate ion concentrations. The effects of ocean acidification (OA) on economically and ecologically important species such as shelled mollusks are of growing concern. We investigated effects of OA on suspension feeding in recently metamorphosed juveniles of the gastropod *Crepidula fornicata*. Brooding adults were collected from southern Puget Sound, WA. They soon released larvae that were then reared under a controlled atmosphere that maintained pH at 7.6 or 8.0. Upon metamorphosis, juveniles were also reared at pH 7.6 or 8.0, so that treatment groups represented 4 combinations of larval and juvenile pH experience. Juveniles were fed daily with *Isochrysis galbana*. Clearance rates were measured by flow cytometry during the first 3 h following introduction of fresh food and seawater. Among juveniles reared at pH 8.0 and tested 36 h after metamorphosis, individuals derived from pH 7.6 larval cultures fed at lower rates than those derived from pH 8.0 larval cultures. 2-4 d after metamorphosis, juveniles with equivalent larval pH experience fed at lower rates at pH 7.6 than at 8.0. However, clearance rates did not differ for older juveniles that were reared as larvae on a benchtop in ambient seawater at pH 7.8-8.0 and, upon metamorphosis, reared for 20 d as juveniles at pH 7.6 or 8.0. The differences in clearance rates observed in young juveniles were most pronounced in the first hour after feeding, which may suggest a reduced response to food under OA conditions. This may be an important consequence of OA for suspension feeders that exploit temporally and spatially variable food resources.

P3-72 LITTLE-JACKSON, NA*; IVANINA, A; Johnson C. Smith University, Univ. of North Carolina, Charlotte; *nal-jackson.2014@mymail.jcsu.edu*

Compartmentalization of Crassostrea virginica hemocytes functions and their modulation by anoxia

Oysters' hemocytes (HCs) play an important role in immune homeostasis and represent diverse cell types with morphological and functional heterogeneity. Environmental factors such as anoxia can modulate functions of HCs and as a results increase oyster's susceptibility to infections. This study determines the effect of low oxygen, as a commonly present stressor in estuaries during summer months on HCs of eastern oyster Crassostrea virginica. We isolated four different subpopulations of HCs from oysters exposed to normoxia (100% O_2) or anoxia (0.1% O_2) and compared their metabolic activity, functions and gene expression profiles. All isolated fractions of HCs showed similar metabolic activity and similar ability to phagocyte, which was not affected by anoxia. mRNA transcripts of pattern recognition molecules and stress response elements were present in all HCs subpopulations. All subpopulations of HCs played role in bacterial recognition based on similar level expression of TLR4 which was not modulated by anoxia. Among all HCs, subpopulation H2 played role in recognizes tissue damage (based on expression of SRCR). Exposure to anoxia significantly decreased the expression of this transcript. Expression of C-type lectin was elevated in subpopulations H1 and H4 and significantly decreased under anoxia exposure. Anoxic conditions significantly elevated the expression of the Tumor Necrosis Factor in fraction H3, hence, demonstrating an increase in inflammation response. Our study shows considerable functional specialization (revealed by the gene expression patterns) between different subpopulations of HCs and modulation of each subpopulation' functions by anoxia.

P3-146 LIU, LG*; LE PIANE, K; CLARK, CJ; University of California, Riverside; *lliu031@ucr.edu*

Barred Owl (Strix varia) Feather Pennulae and Their Role in Reducing Structural Noise in Flight

Owls have silent flight, an adaptation for nocturnal hunting. One wing and feather structure thought to contribute to their ability to fly silently is a "velvety" dorsal surface on their flight feathers. This dorsal surface is derived from the elongated pennulae of feather barbules. How the velvet surface functions to reduce noise during flight is unclear. The aerodynamic noise hypothesis is that the elongated pennulae reduce aerodynamic noise caused by turbulence on the dorsal surface of the wing. By contrast, the structural noise hypothesis posits that the pennulae instead reduce noise produced by feathers sliding past one another during flight. We tested the structural noise hypothesis by measuring the sound produced by two feathers sliding past each other. According to the structural noise hypothesis, manipulating the pennulae (with hairspray) would result in an increase in structural sound produced, whereas manipulating feathers from other birds (that lack elongated pennulae) would have no such effect. Adjacent flight feathers were rubbed together at different speeds under three treatments: no treatment, hairspray, and hairspray removed. Our results have implications for ‘bio inspired' silent flight.

P3-22 LIU, Y*; MURRAY, JA; CAIN, SD; U Illinois at Urbana-Champaign, California State U East Bay, Eastern Oregon U; *james.murray@csueastbay.edu*

See through sea star eyes: a study on the optic cushion of Pycnopodia helianthoides

Starfishes possess compound eyes at the tip of each of their arms. Some species use low-resolution vision to navigate towards the reef. But the mechanisms of visual coding remain largely unknown. Here we describe the morphology and show the adaptation pattern of the eye. The eyes sit on the terminal tube foot and have dozens of orange ommatidia. SEM images show the diameters of the surface of ommatidia vary from 10µm to 40µm. Those closer to the ambulacral groove are considerably larger than the rest with a diameter around 35µm and more folding and evaginating subunits within. The eyes are surrounded by a crown-like structure made up of 20 to 30 hardened tube feet. Purple modified tube feet were located oral and proximal to the eye. When exposed to pulses of light for 80ms or more, we recorded a maximum field potential of ~100-350 µV with a suction electrode in contact with 1-4 ommatidia. The crest-to-trough duration ranged from 1.5s-1.7s regardless of stimulus intensity. As the duration of light stimuli decreased, the response amplitude showed a negative concave down curve. Repetitive light stimuli showed frequency-dependent adaptation. Light pulses with 67s intervals (0.015 pps) elicit responses with decreasing amplitude. After 5 stimuli, the response decreased to 85% of the initial response. When exposed to light pulses with 20s intervals (0.05 pps), however, the pattern is different. The second response dropped to 42% of initial response and the third response recovered to 50%. From there, the responses decreased with repetitive stimuli. At the 7th stimulus, the responses returned to the same amplitude of the second response. With high-frequency stimuli at 10s intervals, the adaptation was strong with the second and subsequent responses dropped to 20% of the initial response. There seemed to be a fast, large response merged with a slow, small response.

96-6 LIU, P*; WANG, X; YEUNG, D; CHENG, B; Pennsylvania State University; *pan.liu@psu.edu*

Flight Control of Landing Maneuvers in Bluebottle Flies

Flies receive the accolade of being eminent fliers for their capabilities of performing precisely coordinated aerial manoeuvers. Landing upside down on the ceiling, for example, is arguably one of the most remarkable flight behaviors of flies when they execute a sequence of precisely- controlled body maneuvers to rapidly align its body with the ceiling under stringent time constraints. In this study, we recorded 58 successful landings of bluebottle flies (Calliphora vomitoria), 22 of which were accomplished through a sequence of body angular maneuvers, and the rest rely primarily on forelegs groping the ceiling and lifting bodies upwards. In the former, the angular maneuvers are dominated by variable combinations of body pitch or roll rotations. It is known that landing of flies is mainly guided by visual cues derived from the optical flow field. Previous studies show that the visual cues such as relative radial expansion rate (RREV) and angular velocity of the landing surface perceived by flies play important roles in triggering and control the landing manoeuvers. Our analysis suggests that RREV instead of landing surface angular velocity is most likely to be the visual cue that triggers the angular maneuver, similar to triggering mechanisms for the deceleration and leg extension found in previous studies on landings on vertical surfaces. Moreover, the strong correlations between the peak angular rate and the magnitude of preceding visual cues or body linear velocities indicate that the landing is precisely controlled by visual and/or mechanosensory cues. To generate the angular manoeuvers during landing, flies use bilaterally symmetric and asymmetric wing kinematic changes, such as fore/aft tilting of stroke plane, shifting the mean wing pitch angle and lateral tilt of stroke plane.

108-4 LIU, Y-C*; GRASSE, B; University of Utah, Marine Biological Laboratory; *yen-chyi.liu@neuro.utah.edu*

Electrical Coupling Characteristics of Chromatophore Muscles in Hatchling Squid Sepioteuthis lessoniana

Cephalopods have remarkable camouflage abilities that rely on the expansion and contraction of tiny pigment organs in the skin called chromatophores. These organs are composed of a central pigment sac attached to a ring of spoke-like chromatophore muscles. The muscles are innervated by motoneurons originating in the brain which project their axons via the pallial nerve. When activated, chromatophore muscles contract, expanding the pigment sac to several times its original size, making it more visible to the eye. Previous work on chromatophore muscles identified neural inputs and revealed electrical coupling between adjacent muscles of the same chromatophore. Here we used the hatching squid (*Sepioteuthis lessoniana*) to further investigate the response of chromatophore muscles to neural inputs and determine the characteristics of electrical coupling between muscles. We conducted dual whole cell patch clamp recordings from muscle pairs of the same chromatophore positioned at varying locations around the pigment sac. We found a high degree of electrical coupling between all muscle pairs in square wave current injection experiments, even when they were positioned opposite one another around the chromatophore. We also recorded spontaneous activity and responses to stimulation of the pallial nerve in muscle pairs. We found that spontaneous and evoked activity in all muscles of the same chromatophore were highly correlated in timing and amplitude, regardless the location of the muscles around the chromatophore. Our results suggest that extensive electrical coupling functions in causing the chromatophore muscles to activate together and expand evenly, producing a circular expansion of the pigment sac that may be more efficient in generating color change.

P2-259 LIU, Y*; NOREKIAN, T; GILLETTE, R; University of Illinois at Urbana-Champaign, Arizona State University; *rhanor@illinois.edu*

Hacking the Sensory Peripheral Nervous System in a Predatory Mollusc

The peripheral nervous system (PNS) of soft-bodied animals like molluscs is known to carry out complex sensory-motor computations, but little is known about the actual neural mechanisms. The notaspid sea-slug *Pleurobranchaea californica* relies heavily on chemotactile information from its anterior oral veil to locate and identify prey. We have previously found that 1) the PNS of the oral veil integrates input from multiple sites to send a somatotopic sensory map of sensory stimuli to the CNS for motor patterning of the turn response; and 2) Putatively dopaminergic sensory cells exist in the PNS with small axons afferent to the CNS; and 3) Dopamine and GABA have integral roles in peripheral sensory integration. Until now the PNS has not been easily accessible to electrophysiological analyses, in part because the afferent axons carrying appetitive and nociceptive sensory information to the CNS are likely too small to be recorded with conventional methods. However, recently we have found that local computations for chemical and tactile responses are accessible in simple suction electrode recordings of the chemotactile oral veil papillae. Whole-mount staining with phalloidin and anti-tubulin showed multiple clusters of putative ciliated sensory cells in papillae (dia. 15-25 µm) with associated muscle bands. The clusters could be recorded singly or multiply. Spontaneous activity of multiple units in a cluster was prominent, and was increased by appetitive chemical stimulation with trimethylglycine and shrimp blood, or by tactile stimuli. Some larger units appeared to be shared among clusters. The accessibilities of the papillae to electrophysiological, pharmacological, and morphological analyses appear to open investigation of the PNS to rapid progress.

P2-58 LIU, R. M.*; ZYLBERBERG, M.; VAN HEMERT, C.; HANDEL, C. M.; DERISI, J. L.; University of California, Santa Barbara, University of California, San Francisco, U.S. Geological Survey, Alaska Science Center, U.S. Geological Survey, Alaska Science Center; *rae.chel.liu@gmail.com*

Elucidating the cause of epidemic beak deformities across species: Poecivirus in North American birds with Avian Keratin Disorder

Avian keratin disorder (AKD), a disease characterized by debilitating beak overgrowth but with unknown etiology, has increasingly affected wild bird populations since the 1990s. A previous study showed that a novel picornavirus, poecivirus, is closely correlated with disease status in black-capped chickadees (*Poecile atricapillus*) in Alaska. While the presence of poecivirus has been well documented in black-capped chickadees, the relationship between poecivirus and beak deformities in other species and elsewhere remains unresolved. We investigate the presence of poecivirus in nine individuals from seven different bird species with elongated beaks consistent with AKD that were sampled from Alaska, Washington, and Maine (red-breasted nuthatch, northwestern crow, blackpoll warbler, mew gull, black-billed magpie, hairy woodpecker, red-tailed hawk). We used targeted PCR followed by Sanger sequencing to test for the presence of poecivirus in each individual, and to obtain viral genome sequence from virus positive host individuals. We detected poecivirus in the beak or cloaca of all tested individuals, and obtained the complete coding region of poecivirus from a red-breasted nuthatch. This study has demonstrated that poecivirus is present in deformed individuals of seven additional species of wild birds, strengthening the correlation between poecivirus and AKD, and providing further support for poecivirus as a candidate agent of AKD across North America.

107-7 LIZÁRRAGA, D; PERNET, B*; California State University Long Beach; *bruno.pernet@csulb.edu*

Large inedible particles may reduce feeding performance of echinoderm larvae in nature

Food concentration may often be so low as to limit growth of the feeding larvae of marine invertebrates, extending larval planktonic duration or reducing juvenile quality. Another challenge facing larvae is that in addition to food, the plankton contains particles that are too large to ingest but which may interfere with feeding. In simplified laboratory conditions, Lizárraga et al. (2017, *Mar. Biol.* 164:102) found that large inedible beads or centric diatoms at concentrations of 25-500 mL^{-1} reduced ingestion of edible particles by echinoderm larvae by up to 80%. Does the assemblage of large inedible particles present in natural plankton have similar effects on larval feeding? On two days in spring 2017, we offered larvae of the sand dollar *Dendraster excentricus* 6 µm beads in natural seawater filtered so as to contain either no particles (0.2 µm filter), natural food only (35 µm filter), or natural food and large inedible particles (200 µm filter). In the first experiment, large centric diatoms were abundant (~90 mL^{-1}) in the 200 µm-filtered treatment, and ingestion of 6 µm beads in that treatment was reduced by $\geq$40% compared to other treatments. In the second, centric diatoms were rare but large pennate diatoms were abundant (~125 mL^{-1}); these did not affect larval ingestion. These results suggest that some types of naturally occurring large inedible particles at natural concentrations may interfere with larval feeding, potentially exacerbating effects of food limitation. In future studies we will compare the effects of different types of large particles on larval ingestion, and the effects of large inedible particles on larval planktonic duration and juvenile quality.

P1-111 LLOSA, I*; COLGAN, W; HARRIS, L; LEANZA, A; HWANG, A; DEBIASSE, M; RYAN, J; DAVIDSON, B; Swarthmore College, Whitney Lab, Univ. of Florida; *illosa1@swarthmore.edu*

Evolution of the heart enhancers in a chordate gene regulatory network

Extensive work has characterized the heart gene regulatory network for invertebrate chordate, *Ciona intestinalis*. *Ciona* is used for studying developmental gene regulation due to shared characteristics with vertebrates in initial cardiac development, along with its smaller and more accessible genome. We have recently sequenced the genome of a related species *Corella inflata* in order to investigate the evolution of gene regulatory networks. Previous computational analysis indicates that the *FoxF* heart lineage enhancer is highly conserved in sequence and organization of binding sites across *Ciona* and *Corella*. However, the evolution of other cardiac developmental enhancers in *Ciona* and *Corella* remains largely uncharacterized. Here we show that the *Corella Hand-like* enhancer is less strictly conserved than *FoxF*. Specifically, transcription factor binding sites in the *Hand-like* enhancer are conserved, but their orientation and distribution have diverged. This indicates that the selective evolutionary pressures exerted on different regulatory nodes in a developmental gene network may differ in intensity. Our results provide insight into the complexity of chordate enhancer sequence evolution. Our continuing analysis of the *Hand-like* enhancer will provide a valuable framework for future comparative analysis.

4-4 LLOYD, MM; PESPENI, MH*; University of Vermont; *mpespeni@uvm.edu*

Shifts in the microbiome with onset and progression of Sea Star Wasting Disease revealed through time course sampling

The most recent outbreak of sea star wasting disease is one of the largest epizootics in history, but the interacting microbes associated with symptom progression have not been identified. Here, we used time course microbiome analysis of sea stars with and without Sea Star Wasting Disease to identify microbial community changes specific to symptom onset and progression. We identified shifts in the microbial communities of individuals that became sick that were distinct from the communities of individuals that remained healthy. The most notable change in microbial communities of sick individuals was the decrease of *Pseudoalteromonas* spp. as symptoms were first observed and through symptom progression. This decrease was followed by an increase of *Tenacibaculum* spp. and *Polaribacter* spp. in early disease stages, and an increase in *Phaobacter* spp and *Polaribacter* spp. late in disease stages. Functional profiling revealed that the microbial communities of healthy stars produced secondary metabolites and degraded xenobiotics, whereas the microbial communities of sick stars performed functions related to basic growth and metabolism. These results have identified the key microbial players associated with specific disease stages in Sea Star Wasting Disease and suggest that symptom onset and progression may be the result of complex interactions between multiple microbial taxa.

125-4 LOCKWOOD, BL*; GUPTA, T; SCAVOTTO, R; University of Vermont; *Brent.Lockwood@uvm.edu*

Disparate patterns of thermal adaptation between life stages in temperate vs. tropical Drosophila melanogaster

Many terrestrial ectothermic species exhibit limited variation in upper thermal tolerance across latitude. However, these trends may not signify limited adaptive capacity to increase thermal tolerance in the face of climate change. Instead, thermal tolerance may be similar among populations because behavioral thermoregulation by mobile organisms or life stages may buffer natural selection for thermal tolerance. We compared thermal tolerance of adults and embryos among natural populations of *Drosophila melanogaster* from a broad range of thermal habitats around the globe to assess natural variation of thermal tolerance in mobile vs. immobile life stages. We found no variation among populations in adult thermal tolerance, but embryonic thermal tolerance was higher in tropical than in temperate regions. Average maximum temperature of the warmest month of the year predicted embryonic thermal tolerance in tropical but not temperate sites. We further report that embryos live closer to their upper thermal limits than adults—i.e., thermal safety margins are smaller for embryos than adults. F1 hybrid embryos from crosses between temperate and tropical populations had thermal tolerance that matched that of tropical embryos, suggesting phenotypic dominance of heat-tolerant alleles. Together our findings demonstrate that embryonic thermal tolerance readily evolves and suggest that selection for thermal tolerance may be limited in adults. Further, our results suggest that thermal traits should be measured across life stages in order to better predict adaptive limits.

113-1 LOGAN, ML*; CURLIS, JD; GILBERT, AL; MILES, DB; CHUNG, A; MCGLOTHLIN, JW; COX, RM; Smithsonian Tropical Research Institute, Georgia Southern University, Ohio University, Ohio University, Virginia Tech, University of Virginia ; *mike.logan1983@gmail.com*

Genetic constraints on adaptation to rapid environmental change

The ‘thermal performance curve' is the conceptual foundation of thermal adaptation theory. It describes the relationship between fitness (or a fitness proxy) and body temperature. Although these curves are typically used to project the effects of climate change on species with an implicit assumption that they are static in time, it is possible that they can evolve at a rate sufficient to significantly reduce extinction probabilities. Recent analyses have shown that shifts in local climates can result in strong selection on thermal performance curves, hinting at the possibility of rapid evolution. Nevertheless, few data are available on the genetic basis of thermal physiology in vertebrates, and we therefore have limited ability to determine the response to selection. To address this issue, we measured the additive genetic basis of thermal preference and thermal sensitivity of sprint speed in the brown anole lizard (*Anolis sagrei*) reared in a common garden experiment. Our previous work revealed that this species undergoes strong directional selection in nature when exposed to a rapid change in their thermal environment. Nevertheless, using both traditional and function-valued approaches, we show that parameters of the thermal performance curve in the brown anole have low or undetectable narrow-sense heritabilities, suggesting that selection is unlikely to result in rapid evolution. By contrast, aspects of thermal preference are highly heritable, implying that thermoregulatory behavior can evolve quickly. Our results suggest that the most likely avenues of short-term adaptation to climate change in the brown anole are evolutionary change in thermoregulatory efficiency and plastic change in thermal physiology.

P1-285 LONG, NP*; FARINA, SC; Dickinson College, Harvard University; *longn@dickinson.edu*

Functional Morphology of the Specialized Gill Chamber in Chaunacidae

Chaunacidae (sea toads and coffinfishes) is a family of anglerfishes (Lophiiformes) specialized for living on the floor of continental slopes at depths of up to 2,500 meters. Like many other Lophiiformes, they are globose sit-and-wait predators. Chaunacids breathe extremely slowly, similarly to some shallow-water anglerfishes (Lophiidae). Lophiids can take up to five minutes to complete a single ventilatory cycle, but the ventilatory rates of chaunacids are unknown. We described the morphology of the chaunacid gill chamber with dissection and micro-CT of preserved *Chaunax suttkusi*. We also analyzed the ventilation of several species from ROV videos by the NOAA Okeanos Explorer. We found that the large gill chambers of chaunacids are lined with thin layers of muscle tissue that extend posteriorly from the branchiostegal musculature to the gill opening, which is positioned behind the pectoral girdle, in the last third of the length of the body. From our video analysis with MATLAB, we determined that chaunacids can hold approximately 27.7% of their body volume in their gill chambers, which can be exhaled in under 6.6 seconds. Unlike in lophiids, who are continuously expanding their gill chambers, chaunacids may be able to hold their gill chamber at maximum expansion for long periods of time. This specialized gill chamber and ventilatory behavior likely assists in the chaunacid life strategy of expending little energy and waiting to ambush prey.

P1-67 LONG, EV*; HOOD, KE; HURLEY, LM; Indiana University; *longede@indiana.edu*

Structure and context of female rejection vocalizations modify behavior in male mice

In rodents, vocalizations of different structure may induce different responses in receivers. During courtship interactions, male house mice (Mus musculus) produce ultrasonic vocalizations (USVs), which are positively correlated to mating success. In the same interactions female mice produce broadband vocalizations (BBVs) that are closely paired with male-directed rejection behaviors. A high initial rate of BBVs corresponds to reduced male mounting success, while the opposite is true of interactions with low initial BBV production. In previous work, playback of a recorded courtship interaction with high initial BBVs in the presence of an inaccessible nonvocalizing female suppresses male courtship USVs. Here, We examined the role of the amount of non-linear structure in BBVs in depressing male courtship USVs, since nonlinear segments vary with individual identity and reproductive state. Males (n=6) were presented with a novel female and BBV playbacks created by using trains of an unmodified exemplar BBV, the same exemplar BBV modified to have no non-linear structure (LowNL) double the non-linear segments (HighNL), or no playback. These 3 playbacks were each presented to a male and female pair separated by a plexiglass barrier with a small opening for olfactory investigation. Males decreased USV production when compared to no playback in response to playback of the exemplar BBV, while increasing USV production in response to LowNL playback, and did not change USV production to HighNL playback. When males were given additional olfactory stimuli, LowNL playback decreased male USV production while other playbacks evoked the previously described responses. These results suggest that male response to female rejection is sensitive to both the structure of rejection vocalizations as well as the context of those vocalizations.

P3-195 LONG, JH*; FJELLDAL, PG; KRYVI, H; Vassar College, Institute of Marine Research, University of Bergen; *jolong@vassar.edu*

Tapering the tube: development of the cranial and caudal ends of the notochord of Atlantic salmon, Salmo salar.

Most work on the morphology of notochords addresses issues related to the middle of this axial skeleton, where its geometry approximates that of a right, circular cylinder. In this middle region (precaudal and caudal) in Atlantic salmon, *Salmo salar*, the initially unsegmented notochord of the precaudal and caudal regions becomes segmented during development as chordacentra and then complete vertebrae form. But we know nothing about the morphological changes at the cranial and caudal termini. Using a variety of histological techniques, we examined the terminal morphologies of the notochord from embryo to adult. Surprisingly, the notochord at the cranial and caudal termini lacks regular segmentation, even at the adult stage. The adults' urostyle, at the tail tip, persists as a notochord and shows irregular transverse septa, only some of which are complete. This stands in contrast to the cranial terminus of the notochord, which is mineralized, in part, before the precaudal vertebrae, develops very few of the vacuolated chordocytes that characterize the middle of the axial skeleton, and persists in adults as a remnant. In summary, the axial skeleton of salmon shows distinct developmental trajectories in at least three zones: cranial, precaudal-caudal, and urostyle. J.L. was supported by the National Science Foundation (USA, INSPIRE, Special Projects, grant no. 1344227).

P3-21 LONGDEN, K.D.*; REISER, M.B.; HHMI Janelia Research Campus, Ashburn, USA; *longdenk@janelia.hhmi.org*

Wavelength-specific spontaneous flight control in Drosophila

The compound eyes of *Drosophila* express five rhodopsins, each with a distinct sensitivity to the wavelength of light, providing a sensory basis for color vision. What the flies use their color vision for is not well understood because few spontaneous color behaviors have been described. To address this shortfall, we have investigated how color vision influences their flight control. We developed a novel ultraviolet (UV) and green projector system to display wide-field visual stimuli and measured the flight responses of tethered flies by optically recording changes in wing stroke amplitude. First, we found that flies can track the motion of an object, a vertical UV stripe on a green background, regardless of the color intensities used, even when the UV and green intensities are matched so that they provide no luminance contrast. This is achieved because the ON- and OFF-motion pathways have different points of isoluminance: when the UV intensity is matched to the green intensity for OFF-motion, it is still visible for ON-motion, and vice versa. Second, flies stabilize an isoluminant horizon using a rapid phototaxic response to large areas of UV illumination, and this phototaxis has a wavelength tuning distinct from that of ON- and OFF-motion. Third, the steering responses to looms depend on the color of the loom and the background, consistent with the wavelength tuning of the ON- and OFF-motion pathways: they are colorblind for green looms against a UV background, but preserved for UV looms against a green background. Finally, when presented with a uniform scene, the wing beat frequency varies with the intensity of UV and not green light. Our results show how the wavelength of light can influence multiple aspects of flight attitude and control, and allow the operation of color vision circuitry to be investigated in the context of natural behaviors.

P1-23 LOPEZ, WA*; HOFFMANN, SL; PORTER, ME; Florida Atlantic University; *shoffmann2014@fau.edu*

Slice Slice Baby: A Cross-Sectional Analysis of Shark Pectoral Fin Radials

Classic studies on shark swimming generalize pectoral fins as rigid hydrofoils that generate lift. However, morphology varies greatly among sharks and this generalization may not embody the function(s) of pectoral fins in all species. Fins are classified into two groups dependent on the extent to which radials support the fin. Skeletal support is hypothesized to vary among species that inhabit different environments; however, little is known about radial morphology. The cross-sectional anatomy and calcification patterns of batoid cephalic lobe and pectoral radials differed significantly among species and corresponded to differences in locomotor style and habitat use. The goal of this study was to examine the cross-sectional morphology of the radial elements of sharks with differing whole-body morphology, locomotor styles, and habitat use. We calculated the second moment of area, a structure's resistance to bending, at 1cm increments along the fin for three radials: the radial along the leading edge, the longest radial, and the radial supporting the trailing edge. We also measured the cross-sectional area of the whole radial and calcified struts, and calculated the percentage of calcification at each increment. We hypothesized that benthic species have radial elements with the least amount of calcification whereas oceanic species have the highest calcified radials. We also predicted that all species have radials that resist bending in the medial-lateral more so than dorso-ventral bending. We propose that these differences in pectoral fin functional morphology exemplify an evolutionary trade-off where benthic species have flexible pectoral fins that aid in maneuvering rock and reef environments, and oceanic species have stiffer fins that maximize hydrodynamic efficiency for sustained swimming.

P2-144 LOPEZ, T*; GEORGE, SB; Georgia Southern University; *georges@georgiasouthern.edu*

Is Offspring Fitness Linked to Seasonal Changes in a Local Salt Marsh?

The salt marsh is an important ecosystem that fuels many economic industries and acts as a sanctuary for many species of birds, juvenile fish, crustaceans, and plant life. As the environment continues to go through many changes, the effects on salt marshes and their inhabitants are becoming apparent. *Uca pugnax* are abundant fiddler crabs found on a Tybee Island salt marsh. They are commonly found on raised substrate, called mounds, with ribbed mussels, *Geukensia demissa*, and cordgrass, *Spartina alterniflora*, along with many other invertebrates. Mussels filter the water that rises and falls with the tides. These filtering activities increase sediment nutrients for cord grass and fiddler crabs. It is thus expected that higher mussel densities will lead to higher sediment nutrient content. The purpose of this study was to determine nutrient levels of the sediment on small and large mounds and protein content of juvenile fiddler crabs living on these mounds during the spring and summer months at a local salt marsh on Tybee Island, Georgia. Four large and four small mounds were surveyed and abundance of juvenile fiddler crabs, mussels, and *S. alterniflora* estimated. Sediment core samples were taken from each mound to determine water content and nutrient content, respectively, and juvenile fiddler crabs collected to determine whether protein expression differ during the spring and summer months. Organic content of sediment was significantly greater in small mounds and mussel and cordgrass abundance increased significantly between spring and summer. Documenting variation in offspring fitness over time will give us insights into the effects of long-term environmental changes in the salt marsh on fisheries and wildlife.

130-4 LOPEZ, N*; STANKOWICH, T; CSU Long Beach; *nikkip0603@gmail.com*

Correlated Evolution of Antlers and Tusks in Cervids

Tusks are mostly seen on smaller ungulates and used primarily as sexual weapons, whereas larger ungulates lack tusks but instead possess antlers, used as a visual display of social status. There are two Genera of deer that have both antlers and tusks: Muntiacus and Elaphodus. In muntjacs, all fights are preceded by a "dominance display", typically performed by the dominant male, resulting with the subordinate male's withdrawal. A gradual increase in the influence of this display may have led to the reduction in size of tusks and eventual evolution of complex, large antlers due to the rarity of fighting. The current project will study the correlation between antlers and tusks in relation to overall body size and other ecological factors. We hypothesize that as body size increases, relative size of tusks will decrease and the relative length of antlers will increase. Antler and tusk data on several species of cervids have been collected from the museum specimens. We will use this data to determine the correlation by using phylogenetic generalized least squares tests, which are regression type tests that take species relatedness into account. Our preliminary studies suggest that as the species move from closed to open habitats, from solitary to group living lifestyles, and from small to large body sizes there is a significant trend of decrease in tusk size and increase in antler size. We propose to examine the effects of environmental and social factors, such as habitat type and fighting style, on the evolution of these traits. The significance of the question is that it would help contribute to our understanding of the selective forces that led to the transition between small solitary tusked deer and large social/polygynous antlered deer.

P1-237 LOPEZ-CERON, A*; DAS, S; MYKLES, D; Colorado State University; *alopcer@rams.colostate.edu*

A transcriptomic approach for the characterization and expression of Sirtuin stress genes in the decapod crustacean molting gland

Crustaceans progress through the intermolt, premolt, and postmolt stages during the molt process to shed their old exoskeleton and grow. The Y-organ (YO) controls molting processes through the synthesis of molting hormones (ecdysteroids). Environmental stress inhibits molting by repressing ecdysteroids by the YO. The purpose of the study is to identify and characterize mRNA sequences encoding stress-response genes in a *de novo*-assembled transcriptome of the YO of the blackback land crab, *Gecarcinus lateralis*. Here we report the identification and expression of Sirtuin genes to understand how external and internal stressors may inhibit molting. Sirtuin family includes seven orthologs (Sirt1 - Sirt7) distributed in four classes regulating important biological pathways in bacteria and eukaryotes. Sirtuins deacetylase target substrates on nicotinamide adenine dinucleotide (NAD+) availability as a cofactor. Their function has been associated with caloric restriction, energy metabolism, and stress resistance. In stress occurrence, Sirtuins promote resistance and cell survival through suppression of genes and pathways associated to specific transcription factors identified in mammals. Contigs encoding Sirtuins 1, 4, 5, and 7 were identified. Amino acid sequences shared some residues in the core region but differed in structure of N- and C- terminal domains. Differences in residues of the terminal regions describe characteristic biological properties of these proteins in three subcellular localizations. Relative expression of Sirtuins from intermolt to postmolt stage of *G. lateralis* exposed an important decrease in mean FPKM ($p<0.05$). The presence of Sirtuin sequences in the YO suggests that environmental stressors inhibit molting by acting directly on the YO. Supported by NSF (IOS-1257732).

S4-11 LORDITCH, E; American Institute of Physics;
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Tools for Science Communication from the Intersection of Journalism and Screenwriting
It is more critical than ever that scientists effectively communicate their research (whether to students, a grant committee, family, policymakers or the person standing in line behind you at the grocery store), but few programs offer scientists with the necessary tools and perspectives to do so. As a professional science writer for the last 19 years, I have learned the power of compelling science narratives for print and online publications and want to share some of my favorite tips for making science communication informative and entertaining. By painting a visual image for your audience, whether through images, graphics, video, or other unique media, a scientist's research becomes an intriguing and relatable tale. My work with the entertainment industry over the last several years has given me a unique perspective on how to reach broader audiences and find new ways to introduce science into storytelling. Storytelling can give research a "face" and science can inspire imaginative stories. By examining science communication from the perspectives of a scientist, journalist and screenwriter, I will show how each point-of-view complements and enhances each other. People love to tell and listen to stories. For example, scientific theories are really narratives and scientists are already telling stories all the time without even realizing it. When you share your passion and also your research struggles, you can engage an audience more effectively than by stating a laundry list of facts and figures. For screenwriters, I discovered that I could offer science truth that was more fascinating than their science fiction ideas. Both of these ideas are supported by my experience and research in the field of science communication.

141-8 LOUDON, C*; BRADLEY, TJ; Univ. of California, Irvine;
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Blood Feeding Increases Body Temperature and Running Speed in the Insect Rhodnius prolixus
The body temperature of small ectotherms such as insects is determined passively through interactions with their thermal environment as well as more actively through muscle contractions that can produce regional endothermy. Elevated temperatures facilitate digestion, reproduction, and locomotion. We examined a possible additional source of warming, namely blood feeding in the insect *Rhodnius prolixus*. Surface body temperatures of the insects were measured using a thermal camera (FLIR ThermaCAM B2). After blood feeding to repletion on a rabbit, the body temperatures of the insects (32.1±0.4C, mean±SE) were significantly elevated over the room temperature (22C) and over insects placed on the rabbit but not feeding (29.6±0.4C). The difference in temperature between a warmed bug removed from the host and room temperature declined 90% in 5.4 minutes (nymphs) and 7.8 minutes (adult males). *Rhodnius* are cryptic and thigmotropic, rapidly seeking cover if placed in the open. We placed *Rhodnius* in an open arena and measured running speed as they sought cover. With body temperatures equilibrated to room temperature, fed nymphs ran significantly more slowly (4.7±1.0 cm/s) than unfed ones (7.9±0.7 cm/s). When tested at the temperatures occurring after blood-feeding, fed nymphs increased their running speed significantly (10.9±0.8 cm/s). We obtained similar results with adult male *Rhodnius*. We conclude that blood feeding significantly elevates the body temperature of both nymphs and adults of *Rhodnius prolixus*. Following blood feeding, body temperature remains elevated for several minutes. The capacity of the insects to flee the host and return to safe hiding refuges is enhanced by this elevated body temperature.
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35-3 LOUGHRAN, CL*; WOLF, BO; University of New Mexico;
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The Costs of Being Cool: Panting Thresholds, Thermal limits, and Evaporative Cooling in Southwestern Lizard Communities
In the American Southwest, operative environmental temperatures (T_e) often exceed what is physiologically tenable for many reptilian species. When faced with extreme environmental temperatures, lizards must either retreat to thermal refugia or attempt to maintain or lower body temperature (T_b) through evaporative processes such as open-mouth panting. Currently, the capacities for evaporative heat dissipation are largely unknown as are the relative efficiencies of evaporative cooling for various species. To better understand the role of panting in body temperature defense against extreme environmental temperatures, we measured thermoregulatory performance for a variety of lizard species native to the southwest. We used flow-through respirometry to gather data on standard metabolic rate (SMR) and evaporative water loss (EWL) at air temperatures (T_a) that ranged from 35°C to 50°C. Concurrently, we used a live-streaming camera to monitor lizard activity, and panting initiation, and T_b in real-time using thermocouples that were inserted into the lizard's cloaca. We found SMR and EWL increased steeply following the onset of panting, with the ability to maintain a gradient between T_a and T_b strongly associated with EWL rate. Species inhabiting hot desert environments had higher panting thresholds, were much more efficient at dissipating heat, and tolerated higher T_a's and T_b's for longer periods than species adapted to more mesic environments. Identifying the onset of panting, the capacity for heat defense and its relationship to critical thermal limits should provide valuable insight into how climate warming may impact lizard activity and hence water and energy budgets under future climates.

131-7 LOUIS, MP*; CASTRO, AA; CADNEY, MD; KAZZAZI, L; GARLAND JR, T; University of California, Riverside;
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Four weeks of wheel access alters lean, fat, and relative organ masses in adult female house mice
Phenotypic plasticity potentially affects all aspects of an organism's adult phenotype. As an example, many studies have demonstrated (adaptive) training effects in response to exercise. In lab rats and mice, 8 weeks of forced or voluntary exercise generally causes many such changes. However, for many traits the amount of training is quantitatively related to the amount of exercise and/or depends on genetic background (e.g., not all individuals train). In the present study, we examined training effects in response to voluntary wheel running over a 4-week period in adult female mice from 4 replicate, selectively bred High Runner (HR) and 4 non-selected control (C) lines. HR mice ran ~3-fold more revolutions/day than C over the course of the study. Wheel access significantly ($P<0.05$) reduced total fat mass and HR mice had less fat than C, based on MRI, with no interaction; however, neither factor affected lean mass. With body mass as a covariate, wheel access also reduced both reproductive and subdermal fat pad masses, the latter especially in C mice. With body mass as covariate, wheel access increased heart mass and HR mice had larger hearts, with no interaction; HR mice also had larger brains. Hematocrit and the relative masses of triceps surae muscles, liver, and spleens were unaffected by either wheel access or linetype. Overall, results show that voluntary exercise for as little as 4 weeks can alter morphological phenotypes of adult female mice, even those that do not engage in high levels of exercise.

116-4 LOUIS, LD*; BOWIE, RCK; DUDLEY, R; Univ. of California, Berkeley; *llouis@berkeley.edu*

Morphological adaptations to hovering in a remarkable radiation of Old World nectarivorous birds: the sunbirds (Nectariniidae)

Hovering is an energetically expensive mode of flight and places high mechanical stress on the avian body. Knowledge of the morphological adaptations for hovering is necessary to elucidate how this behavior evolves and to understand which species are capable of hovering and why. However, only hummingbirds have been thoroughly studied for their morphological adaptations to hovering. We evaluated sunbirds (Family: Nectariniidae), a taxon that includes species that are incapable of hovering and species that routinely hover. We collected linear measurements of wing, tarsus, and bill length from 75 sunbird species. We also collected linear and areal measurements of long bones from 40 sunbird species using computed tomography scanning. The species we chose covered a wide range of hovering abilities and resident elevations. After accounting for phylogenetic history, we found that overall bird size increased with elevation, and that the ulna is rounder in birds that hover more frequently. Skeletal morphology can thus provide clues for behavior in closely related species, and elucidate the evolutionary origins of hovering behavior.

P3-71 LOVE, AC*; GRISHAM, K; DURANT, SE; Oklahoma State University, Oklahoma State University, University of Arkansas; *ashley.c.love@okstate.edu*

Can Social Cues of Infection Activate Innate Immune Responses?

While it is well-established that infection can lead to changes in physiology, less is known about how visual exposure to diseased conspecifics can influence an organism's physiological state. Such social cues of infection can result in avoidance behavior, but less is known about how these cues affect the immune system. Exposure to a perceived immune threat could stimulate innate immune responses, which would increase the response time to an immune threat and potentially reduce susceptibility to infection. To test this, we examined how social cues of infection affect complement activity, white blood cell differentials, and cytokine gene expression in canaries (*Serinus canaria domestica*) that are housed in visual contact with either control conspecifics or conspecifics infected with the bacterium *Mycoplasma gallisepticum*. Our preliminary data suggests that immune activation occurs in birds exposed to a social cue of infection around 6-12 days post-inoculation, which is also when infected stimulus birds exhibited the greatest degree of lethargy and disease severity. Future research should explore whether immune activation following a social cue of infection confers any protection against infection, such as increased recovery time or reduced disease severity.

P2-169 LOVELESS, J*; LAGOGIANNIS, K; WEBB, B; University of Edinburgh, King's College London; *s0937976@sms.ed.ac.uk*

Neuromechanical Modelling of Larval Drosophila Exploratory Behaviour

The *Drosophila* larva executes a stereotypical exploratory routine in which it appears to alternate between straight peristaltic crawling and lateral turning events. Contemporary explanations for this behaviour have relied upon putative central pattern generating and decision-making circuits within the larval brain. Taking a novel approach, we have developed a model of larval mechanics which describes axial and transverse motion over a planar substrate, and have used it to postulate a simple, reflexive neuromuscular model based on physical principles. Through principled mechanical analysis, we show that peristaltic crawling may be seen as a natural consequence of the body's tendency to propagate axial elastic waves, while turning results from an energetic coupling between axial and transverse motions which allows peristaltic waves to drive turning motions. Furthermore, this coupling causes the motion of the body to become chaotic and unpredictable, giving rise to spontaneous "transitions" between peristalsis and turning. At a population level, this encourages a view of exploration as an emergent deterministic superdiffusion process which is mechanistically grounded in the physics of the body. Indeed, our neural models do not function as decision makers or pattern generators, but rather as amplifiers or filters for sensory feedback; they selectively emphasize patterns which are already present within the dynamics of the body. Most strikingly, the coupling of axial and transverse degrees of freedom means that an entire exploratory routine can be produced without any explicit sensing or control of turning, and without any decisions regarding when to transition between behavioural states.

S4-12 LOVERD, R*; ELSHAFIE, S; SUMIDA, S; GERBIN, CS; The Science & Entertainment Exchange, UC Berkeley, CSU San Bernardino; *rloverd@nas.edu*

Improving Depictions of Science in Mainstream Media

An extensive body of literature concludes that utilizing story structure for teaching and learning improves recall and understanding of new information. Placing facts into a storyline aids retention in the context of a broader narrative. The Science & Entertainment Exchange (The Exchange), an outreach program of The National Academy of Sciences, aims to inspire better science in Hollywood by introducing entertainment professionals to great science communicators through consultations and events. The goal of this effort is to inspire more and better science in narrative mainstream media, as well as positive portrayals of STEM professionals, in order to disseminate accurate information to the general public. Since its launch in 2008, The Exchange has completed more than 2,000 consults on films such as AVENGERS, STAR TREK: INTO THE DARKNESS, BLACK PANTHER, and BIG HERO 6. Additionally the program has produced more than 250 live events, primarily in New York and Los Angeles. Over the course of the program's eight years, it has built a guest list of 6,000 entertainment professionals and scientists and created a database of more than 2,700 science communicators. The Exchange's ongoing work, as well as those of scientists, engineers, and medical professionals who take additional time to work as film and media consultants, improves STEM depictions and brings more science to the public in the form of narrative. Mainstream fiction can play a critical role in inspiring interest and public sentiment. It can also provide "teachable moments" about science and convey important facts that are better retained than when they are conventionally taught. We describe the mission and activity of The Exchange as a model for science engagement with the public, and discuss the future potential impact of popular media on science literacy and perception.

3-3 LOWDER, KB*; DEVRIES, MS; KELLY, CB; TAYLOR, JRA; Scripps Oceanography, UC San Diego; *kblowder@ucsd.edu*

Spiny lobster defenses here and there: effectiveness of near and far range predator defenses are compromised by ocean acidification-like conditions

Spiny lobsters boast predator defenses that function at far and near ranges to comprise multi-tiered protection. These include antennule flicking to detect distant sources of chemical cues, long antennae that push away interlopers, and a spiny exoskeleton to act as armor. Due to incorporating external elements in the exoskeleton and relying on external chemical cues, changes to ocean chemistry (ocean acidification) have the potential to disrupt these multiple modes of defense. We exposed 64 juvenile California spiny lobsters (*Panulirus interruptus*) to either ambient pH (7.97) or one of three reduced pH treatments (stable pH, 7.67; two levels of diurnal fluctuating pH, 7.67 ±0.05 and ±0.10) for three months. We then introduced a chemical cue (mussel slurry) to lobster tanks and recorded antennule flicking rate. We also examined the structure and mechanical properties of three exoskeleton regions (carapace, horn, and antenna) using SEM and nanoindentation. Preliminary results indicate that lobsters in ambient conditions responded to chemical cues with increased antennule flicking, but this response was significantly depressed in lobsters in reduced-pH water, indicating potential changes to either the cue molecules or sensory cells. Exposure to fluctuating reduced pH decreased the hardness of the horn and carapace in comparison to those in ambient and stable reduced pH, although there were no detectable changes in exoskeleton structure. These results demonstrate the importance of implementing natural environmental variation while also revealing that the defenses allowing spiny lobsters to detect threats from a distance and defend themselves at close range may be compromised under ocean acidification conditions.

P1-276 LOWE, AD*; PAIG-TRAN, EW; California State University, Fullerton; *alowe@csu.fullerton.edu*

Tiny Tanks Of The Amazon: Mineralization And Imbrication Of A Small Armored Catfish, Corydoras panda

The panda cory catfish, *Corydoras panda*, is a small (maximum total length = 7.5 cm) armored catfish in the family Callichthyidae that lives in clear, fast-moving waters of South America. The body is covered by two rows of repeating, overlapping scutes that, presumably, serve to protect the fish from penetration via tooth puncture. The composition of the scutes has been described as having a superficial layer of highly mineralized, non-osseous, and non-collagenous hyaloine tissue covering a deeper bony base. Currently, there is no information describing the amount of scale overlap and mineralization of this hyaloine layer. The goal of this study was to provide insight into the composition (weight ratio of inorganic, organic, and water) and percent imbrication (overlap) of panda catfish scutes. The scutes are composed of 45% inorganic material, 15% organic, and 40% water content. The mineral content was similar to other armored fishes (*Arapaima gigas* scales 39%, *Atractosteus spatula* scales 20-98%, and *Morone saxitilis* scales 46%). However, the relatively low organic content with high water content is atypically high compared to these other fishes. The degree of scute imbrication was similar across the body with 26% overlap at the anterior region, 34% at the middle, and 32% at the posterior region. The degree of overlap was less than in *A. gigas* (60%) and Cyprinid species (up to 86%) and closer to that of *A. spatula* scales (30%). Despite their differences in scale shape and how the scales are connected, *C. panda* armor is most similar to the armor of *A. spatula*, for percent imbrication and in composition, as both are comprised of a mineralized layer overlaying a bony base.

103-7 LOWE, J*; MINOR, P; ANDRADE LOPEZ, J; GREEN, S; Stanford University, Caltech; *clowe@stanford.edu*

Patterning contrasting body plans with deeply conserved developmental programs.

The origin of the vertebrate head has been a topic of debate for over a century. Much of what we understand about the origins of our own complex body plan has been based on comparative studies between the body plan of vertebrates and the simpler basal chordate lineages. Our work adds a new perspective to the origins of vertebrates: Hemichordates are a phylum closely related to chordates, but with a contrasting body plan. Despite this organizational and morphological disparity, our detailed studies using both descriptive and functional approaches reveal that hemichordate and vertebrate anterior developmental programs share some exquisite similarities. Surprisingly, recent transgenic approaches have revealed some of this conservation is a result of deep conservation of the underlying regulatory logic, not shared with basal chordates, despite their much closer morphological affinities with vertebrates. I will discuss the implications of our findings for early vertebrate origins, but also what our data suggests about the rather loose connection between gene regulatory network and morphological evolution.

P3-33 LUBECK, LA*; LUNSFORD, ET; HAEHNEL-TAGUCHI, M; LIAO, JC; Whitney Laboratory for Marine Bioscience, University of Florida and Brown University, Providence, RI, Whitney Laboratory for Marine Bioscience, University of Florida, Frieberg University, Germany; *lauren_lubeck@brown.edu*

Live-imaging reveals organization of efferent neurons in the zebrafish lateral line system

The lateral line system in fishes helps them sense the water flow in their environment, and is a powerful model to better understand the functional architecture of vertebrate hair cell systems. The lateral line is made up of neuromasts composed of bundles of mechanosensory hair cells. These hair cells are innervated by two types of neurons: afferent neurons and efferent neurons. The afferents receive information while the efferents can desensitize the lateral line system during self-generated motions. How efferent neurons are spatially organized? Specifically, we are interested in whether there is a somatotopic arrangement, as has been found for the afferent lateral line neurons. In order to visualize the efferent neurons in the hindbrain of 4-6 dpf larval zebrafish, *Danio rerio*, we used Islet GFP fish, a transgenic line that labels the efferent neurons. We backfilled the neuromasts along the body by electroporating rhodamine and Alexa 647 (MW 3000 and 10000) with Axoporator 800A (pulse train protocol 50-75v, square pulse, 5.5ms width, 1s duration). We performed live imaging with a Leica SP5 confocal microscope to see if there was a pattern in efferent neuron organization. We discovered that efferent neurons located caudally in the hindbrain innervated caudal neuromasts while efferent neurons located rostrally in the hindbrain innervated rostral neuromasts (n=3 fish). These findings indicate that efferent neurons are indeed dedicated to specific neuromasts along the body. In addition, we discovered fine afferent processes that we hypothesize would contribute to sensory integration between the left and right sides of the animal.

P1-117 LUC, H*; RACZKA, A; CAO, C; WARDEN, M; GROSS, JB; University of Cincinnati, Seven Hills Academy, Summit Country Day; *luchm@mail.uc.edu*

Utilizing in situ hybridization to shed light on the genetics of cave adaptation

As a consequence of adapting to the cave environment, troglobitic organisms demonstrate a variety of extreme phenotypes. To explore the gene expression changes underlying these traits, we study the Mexican tetra, *Astyanax mexicanus*. This species, inclusive of surface and cave-dwelling morphs, provides a powerful comparative paradigm through which we can infer changes to the "ancestral" surface fish in the derived cavefish. Although many genes associated with cave adaptation have been identified through transcriptomic studies, their spatial and temporal expression remains unclear. In this study, we performed a series of *in situ* hybridization analyses (ISH) to assess distinct expression patterns between morphs. We focused on genes associated with neural crest specification, migration and differentiation. The neural crest plays a crucial role in the development of many variable traits between surface and cavefish, including the craniofacial complex, pigmentation and the peripheral nervous system. Utilizing stage-matched embryos across three developmental stages (24 hour post fertilization [hpf], 36 hpf, and 72 hpf), we probed several genes and observed substantial differences in expression in the early cranium and notochord. Current studies are evaluating the function of lesser known genes with different expression levels based on RNA-sequencing studies. This study provides qualitative evidence of early gene expression differences that putatively play a role in survival in the cave microenvironment.

70-1 LUCAS, KN*; TYTELL, ED; LAUDER, GV; Harvard University, Tufts University; *kelsey.n.lucas@gmail.com*

The distribution of thrust and drag on a bluegill sunfish during steady swimming

Many fish are notable for their astonishing swimming abilities, and many of their behaviors such as finding food, migrating, or avoiding predators rely on their ability to swim effectively. As such, an understanding how swimming locomotion arises can help reveal evolutionary pressures leading to the diversity of body forms we see in fishes today, and further, can inspire designs for fast, efficient underwater vehicles. Yet, our ability to understand the nuances of the distributions of these forces and the mechanisms through which they are generated has been limited by the difficulty of measuring forces on a live, freely-swimming fish. Here, we use a recently developed, non-invasive, particle image velocimetry-based method technique to calculate pressure distributions on a bluegill sunfish (*Lepomis macrochirus*) swimming freely using body-caudal fin locomotion. From these pressure data, locomotor forces can be accurately estimated at high spatial and temporal resolution. We describe the distribution of forces and show that thrust and drag are produced in characteristic, separate regions of the body. By looking simultaneously at fish kinematics and the pressure and force distributions, we describe the mechanisms by which swimming forces are produced. In this way, we compare the contributions of low (suction) and high pressure to the thrust and drag acting on a carangiform swimmer, and contrast this with previous work on anguilliform swimming.

75-4 LUGER, AM*; OLLEVIER, A; HERREL, A; ADRIAENS, D; Ghent University, C.N.R.S/M.N.H.N.; *allison.luger@ugent.be*

A Tale of Tails: Variation in Morphology Linked to Tail use in Chamaeleonidae

Chameleons (Chamaeleonidae) use their tails in different ways. Typically, chameleons have an arboreal lifestyle and use their prehensile tails for anchoring and as a support for their acrobatics. There are some genera however, that have a terrestrial lifestyle, such as *Brookesia* and *Rieppeleon* species. This study focuses on the morphological variation in the tail skeleton associated with these lifestyles and how this can be used to explain what makes a tail prehensile. Both interspecific and intra-individual variation in skeletal tail morphology is investigated. We want to link interspecific variation to the overall differences in tail use, whereas regional variation should give us more information on the regional variation in tail use. For this, different species representing each genus of prehensile and non-prehensile chameleons were µCT scanned, and a 3D morphometrical analysis was performed on the vertebral shape. This study found that there are differences between prehensile and non-prehensile chameleons. Non-prehensile tailed species namely have a shorter tail with less vertebrae whereby these vertebrae generally have a shorter neural spine and a transverse process which is positioned more anteriorly. The functional implications of this pattern will be further discussed, relying on muscle attachment sites.

22-4 LUNSFORD, ET*; LIAO, JC; Whitney Laboratory for Marine Bioscience, University of Florida; *elunsford@ufl.edu*

Lateral Line Afferent Neurons Decrease Spike Rate During Motor Activity in Larval Zebrafish

The ability of a moving animal to discriminate external stimuli from self-generated stimuli is important to maintain sensitivity to biologically relevant cues. The lateral line system allows fishes to detect changes in their fluid environment. The deflection of mechanosensory neuromasts by fluid motion results in an increased frequency of action potentials in the afferent neurons. Many studies have investigated the response properties of lateral line neuromasts and afferents, but to better understand the underlying physiological response of neuromast stimulation we must investigate afferent neuron activity in the context of the animal's behavior. During swimming behavior, an efference copy of motor signals may function to modulate afferent activity. Using larval zebrafish (*Danio rerio*) of different ages (4-8 dpf), we quantified how the spontaneous frequency of afferent spikes was modulated during fictive swimming. To do this, we simultaneously recorded from afferent neurons and ventral motor root using extracellular recordings. Several motor activities were elicited (i.e. electrical and visual) and characterized, including swimming across frequencies from 20-50 Hz. During motor activity, afferent spontaneous activity decreased by 72.0%. This relationship was maintained across varying frequencies of motor activity. In addition, there was no significant change in modulation through development. This study suggests that the efferent system indiscriminately modulates the hair cells and/or afferent fibers to limit reafference during voluntary motion.

40-5 LYNCH, LM; Oklahoma State University CHS; *leigha.king@okstate.edu*
Isolation by Pleistocene glaciers resulted in divergence of skeletal limb morphology of North American pine martens, Martes americana and M. caurina
Several North American mammals underwent allopatric speciation during the Wisconsin glaciation (11.7 kya). The retreat of these glaciers resulted in faster expansion of Eastern forests than Western, keeping many Western populations isolated and exposing dispersing Eastern populations to a wider range of biomes. Molecular data suggests pine martens were separated into two species, *Martes americana* and *Martes caurina*, during this period. Skeletal limb morphology supports this separation; however, limb morphology also correlates with biome. I tested for the evolutionary tempo and mode of skeletal limb morphology in *M. americana* and *M. caurina* using 3D geometric morphometric landmark data from limb bones and a Bayesian phylogeny created from the 12S, 16S, cytochrome b, and d-loop sequences. I found that a time dependent evolutionary model, Delta/Independent Evolution, best fits morphological evolution. The evolutionary rates differed, with *M. americana* from broadleaf forests in the eastern U.S. having the fastest rate and *M. caurina* having the slowest. Disparate skeletal limb morphology of the two species evolved early in their speciation as a result of glacial isolation during the Pleistocene. Researchers have hypothesized that after glacial retreat *M. americana* dispersed from a southeastern refugium to most of Canada and Alaska while *M. caurina* remained restricted to the western US. The faster rate of evolution in *M. americana* may correlate with its colonization of most of North America, which includes variable biomes. The slower evolutionary rate of *M. caurina* suggests its morphology represents the ancestral state, but comparison to the extinct noble marten indicates Pleistocene martens were more robust than living.

P3-90 LYNN, SE*; KERN, MD; The College of Wooster; *slynn@wooster.edu*
Corticosterone secretion in response to early life cooling: do age, duration of cooling, and nutritional status matter?
Early life experiences can affect the function of the hypothalamo-pituitary-adrenal (HPA) axis of vertebrates, with the potential for fitness consequences later in life. In altricial species, for example, variations in parental behavior, e.g. brooding or feeding, can modulate HPA axis activation in young by altering their exposure to noxious stimuli during postnatal development. We have shown that a drop in the body temperature of eastern bluebird (*Sialia sialis*) chicks, such as occurs when females are away from the nest, can elevate their blood corticosterone (CORT) levels. Repeated cooling bouts also affect HPA responses to handling beyond the brooding period. Thus, variation in maternal behavior can shape HPA function in chicks. To better understand how maternal absence from the nest activates the HPA axis of bluebird chicks, we experimentally mimicked cooling induced by maternal absence, and investigated a) the age at which the HPA axis becomes capable of responding to cooling by increasing CORT secretion, b) whether prolonged cooling results in prolonged elevations of CORT, and c) whether fasting (also associated with prolonged maternal absence) interacts with cooling to affect CORT secretion. Cooling for 18 min significantly elevated circulating CORT levels of chicks as young as 4 days post-hatch, and the response increased with age thereafter. Cooling bouts of longer duration (up to 54 min) also produced significantly elevated CORT levels in chicks. A 1-hr period of fasting had no effect on CORT secretion, regardless of whether chicks were cooled or not. Collectively, these data demonstrate that variation in maternal brooding behavior can substantially modify CORT profiles during early postnatal development, and that chick temperature is likely the main driver of this.

S3-5 MA, Li; CASTRANOVA, Daniel; WEINSTEIN, Brant M.; GORE, Aniket; JEFFERY, William R.*; University of Maryland, College Park, NICHD, NIH; *jeffery@umd.edu*
Molecular Mechanism of Eye Loss in the Cavefish
The absence of eyes is a hallmark of cave adapted animals. In the teleost *Astyanax mexicanus*, eyeless cavefish (CF) have evolved several times from eyed surface fish (SF) ancestors. CF embryos initiate eye development but eyes stop growing and degenerate in larvae. Despite decades of genetic analysis in *Astyanax*, the mutated genes controlling the eyeless phenotype are still unknown. Here we identify the *cbsa* gene, which is downregulated in the developing CF eye, located in an eye QTL, and harbors a *cis*-acting regulatory mutation. The *cbsa* gene encodes cystathionine beta-synthase, the limiting enzyme of the transsulfuration pathway, which converts homocysteine (hCys) to cystathionine, the precursor of glutathione. We found that hCys concentration is elevated in CF embryos and injection of hCys into eggs causes eye loss in SF embryos. High levels of hCys are known to affect the cardiovascular system. Accordingly, angiography revealed leakages in CF eye vasculature leading to blood hemorrhages, which were not observed in SF. The hemorrhages are repaired within a few days, leaked blood cells are removed by macrophages, and the afflicted CF larva develop into normal adults. Knockdown of *cbsa* in SF induced eye loss, blood vasculature defects, and hemorrhages resembling CF. Regulatory mutations leading to *cbsa* downregulation, elevated hCys levels, and dysfunctional optic vasculature were observed in multiple *Astyanax* CF populations. We conclude that eye loss evolved repeatedly by mutations in the *cbsa* gene and hCys mediated defects in optic blood vasculature, which inhibit growth by imposing anoxia and trophic deprivation on the developing CF eye.

23-1 MACDOUGALL-SHACKLETON, SA*; MOORE, IT; Univ. of Western Ontario, Virginia Tech; *smacdou2@uwo.ca*
Glucocorticoids and "Stress" are Not Synonymous
Because glucocorticoids can be measured in a variety of tissues, as well as feces and urine, using commercially available assays, the measure and manipulation of these hormones has become a widespread tool in field and laboratory studies of stress biology. Unfortunately, with the increased study of cortisol and corticosterone (CORT) there has been an apparent increase in the false equating of CORT with stress. First, many authors refer to CORT as a "stress hormone". It is not. If anything it is an anti-stress hormone. Glucocorticoids are metabolic hormones with numerous target tissues and effects, and the elevation of CORT in response to a stressor is only one component of a complex stress response. Referring to CORT as a stress hormone diminishes the multifaceted effects of CORT and downplays the other components of the stress response. Second, many authors equate CORT administration with applying a stressor. Activation of the HPA axis and increases in plasma CORT are just a small component of the stress response. For this reason, the stress response and CORT administration are not synonymous and misuse of these terms results in problems in both hypotheses and predictions, and maybe more importantly, interpretation of results. In this presentation we present bibliometric data on this issue, as well as specific examples of how the effects of CORT administration can differ from manipulation of stressors. We recommend an increased distinction between stress and CORT in the literature and during presentations. Rather than a minor point of semantics, this distinction is important both for how we design studies and how we interpret their results.

8-4 MACIAS-MUNOZ, A*; MCCULLOCH, KJ; BRISCOE, AD; University of California, Irvine, Harvard University; *amaciasm@uci.edu*

Copy number variation and a role in vision for CRAL-TRIO domain genes in Heliconius melpomene

The CRAL-TRIO domain is a structural region common to proteins that transport hydrophobic tocopherols. In vertebrates (CRALBP) and *Drosophila* (PINTA) CRAL-TRIO domain containing proteins transport vitamin A-derived chromophores that are necessary for vision. Members of the CRAL-TRIO domain gene family have undergone lineage-specific duplications in insects, and an expansion in Lepidoptera. Lepidopterans have twice as many CRAL-TRIO domain genes compared to other insects. However, there is no lepidopteran ortholog of *pinta*. We aimed to 1) characterize the molecular evolution of the CRAL-TRIO domain gene family and to 2) identify a candidate gene for chromophore transport in butterflies. By searching a *de novo* transcriptome and reference genome, we found 43 CRAL-TRIO domain genes in a butterfly species, *Heliconius melpomene*. A phylogeny revealed two duplication events and an expansion of these genes in *H. melpomene*. 36 of the CRAL-TRIO domain genes were located in tandem on 3 chromosomes. We used 18 resequenced genomes from 4 subspecies to detect copy number variation of 32 CRAL-TRIO domain genes. We also performed differential expression analysis using RNA-Seq from the heads, antennae, legs and mouthparts of *H. melpomene* to identify a candidate CRAL-TRIO domain gene, *Hme CTD31*, upregulated in heads. RT-PCR confirmed that *Hme CTD31* is expressed in the retina rather than the brain. Furthermore, immunohistochemistry showed that the Hme CTD31 protein is found in primary and secondary pigment cells. The CRAL-TRIO domain gene family is likely evolving by tandem duplications and a member of this family potentially functions in butterfly visual pigment transport.

P1-167 MACIEJEWSKI, M*; MEYER, KS; PITTOORS, N; WHEELER, JD; ANDERSON, EJ; MULLINEAUX, LS; Stonehill College, Biology Department, Woods Hole Oceanographic Institution, Northern Michigan University, Institute of Environmental Engineering, Department of Civil, Environmental, Geomatic Engineering, ETH Zurich and Biology Department, Woods Hole Oceanographic Institution, Department of Mechanical Engineering, Grove City College; *mfmac96@gmail.com*

Helical swimming as an active feeding behavior in larvae of the eastern oyster

Larvae of the eastern oyster (*Crassostrea virginica*) demonstrate control over swimming velocity and directionality. Larvae have been shown to alter their swimming patterns in response to environmental cues such as light, turbulence, sound, and chemical cues. Larval behaviors in the water column affect the survival of individuals and the maintenance of populations. Therefore, an understanding of larval swimming is informative for population dynamics, as well as aquaculture operations and oyster reef restoration. Helical swimming is a commonly observed behavior in *C. virginica* larvae. It has been proposed that swimming along a sinusoidal path may serve as an antipredator, exploratory, or feeding behavior. In other planktonic species, swimming slowly in circular paths increases feeding efficiency by allowing plankton to maximize time spent in food patches. In this study, we tested the hypothesis that helical swimming is an active feeding behavior in *C. virginica* larvae. We recorded and analyzed swimming behavior of starved and fed larvae, exposed to different food concentrations, in a controlled laboratory setting. We compared swimming velocities and the number and geometry of helices across treatments to discern the influence of satiation and food availability on swimming behavior.

113-5 MACK, KL*; BALLINGER, MA; PHIFER-RIXEY, M; NACHMAN, MW; Univ. of California, Berkeley, Monmouth Univ.; *katyamack@berkeley.edu*

Adaptive variation in gene regulation in mice"

Changes in cis- regulatory regions are thought to play a major role in the genetic basis of adaptation. However, few studies have linked cis-regulatory variation with environmental adaptation in natural populations. Here, using a combination of exome and RNA-seq data, we perform expression quantitative trait locus (eQTL) mapping and allele-specific expression analyses to study the genetic architecture of regulatory variation in wild house mice (Mus musculus domesticus) using individuals from 5 populations collected along a latitudinal cline in eastern North America. Mice in this transect show clinal patterns of variation in several traits, including body mass. Mice are larger in more northern latitudes, in accordance with Bergmann's rule. We identify genes with clinally varying cis-eQTL where expression level is correlated with latitude. Among these clinal outliers, we identify two genes (Adam17 and Bcat2) with cis-eQTL that are associated with body mass variation and for which expression is correlated with body mass within and between populations. These findings demonstrate the power of combining gene expression data with scans for selection to identify candidate genes involved in adaptive phenotypic evolution and also provide strong evidence for cis- regulatory elements as essential loci of adaptive clinal evolution in natural populations.

P1-65 MACKIEWICZ, AG*; MENSINGER, AF; Marine Biological Laboratory, Woods Hole, MA, University of Minnesota, Duluth; *macki059@d.umn.edu*

Using passive acoustics to determine the effect of abiotic and biotic sound on Oyster Toadfish (Opsanus tau) vocalization rates

Acoustic communication is critical for reproductive success in the Oyster Toadfish, *Opsanus tau*. Passive acoustics allows for non-invasive monitoring of fish vocalizations and previous studies have determined the seasonality of toadfish calls in Eel Pond in Woods Hole, MA using a single hydrophone. Over the last century, human activities have increasingly added artificial sounds to the aquatic environment. The purposes of this study were to determine the number and location of vocalizing toadfish in Eel Pond using a multiple hydrophone array and to monitor how different abiotic and biotic factors impact toadfish calls. Numerous motorized watercraft armored in Eel Pond, including the RV Gemma, which presents a unique opportunity to monitor toadfish vocalizations in response to anthropogenic sound. A four-hydrophone linear array was deployed to record underwater sound. The number of calls, amplitude, time interval and location of fish recorded from the hydrophones were analyzed. Six different vocalizing toadfish were located and monitored over the course of the breeding season. Anthropogenic sound produced by the RV Gemma and heavy rain events depressed vocalization rates in toadfish. Boatwhistle playbacks using a previously recorded toadfish call increased the amplitude and number of toadfish calls during the peak mating season. The multiple hydrophone array allowed for individual toadfish locations to be determined and monitored and provided data that shows toadfish vocalization rates can be influenced by anthropogenic, environmental and conspecific sounds.

142-3 MACLEOD, KJ*; LANGKILDE, TL; SHERIFF, MJ; Pennsylvania State University; *kirstyjmacleod@gmail.com*

Maternal stress in eastern fence lizards does not adaptively program offspring to a stressful environment

The maternal environment during gestation can have profound impacts on the phenotype of offspring via transgenerational maternal effects. Transgenerational effects of maternal exposure to environmental stressors have been assumed to be negative. However, more recent work integrating the effects of maternal stress in an ecological framework suggests that maternal stress could benefit offspring if its outcomes better adapt them to life in a stressful environment. In this study we experimentally test the "Environmental Matching" hypothesis in eastern fence lizards (*Sceloporus undulatus*). We subjected gravid female lizards to a chronic low-level stress treatment until laying (topical application of a low-concentration dose of corticosterone, a glucocorticoid hormone produced in response to stressors). This treatment was designed to emulate the physiological effects of a single daily fire-ant attack, an ecologically relevant low-level environmental stressor. Hatchlings produced by these females were then raised in enclosures either with fire ants present or excluded to provide a test of whether maternal stress resulted in offspring better-adapted to stressful environments. Despite effects on offspring phenotype, maternal stress treatment did not influence hatchling survival irrespective of their environment, providing no evidence for the Environmental Matching hypothesis. However, differences in dispersive behavior and habitat use could indicate alternative routes through which maternal stress could influence wild populations. This study suggests that the phenotypic effects of maternal stress, mediated by glucocorticoids, may not translate to differences in fitness-related traits, and that more studies investigating maternal stress in ecological and evolutionary frameworks should quantify effects of phenotypic differences on fitness-related traits.

P2-117 MACRANDER, J*; PANDA, J; JANIES, DA; DALY, M; REITZEL, AM; Univ. of North Carolina at Charlotte, The Ohio State University; *jmacrand@uncc.edu*

Venomix: A Simple Bioinformatic Pipeline for Identifying and Characterizing Toxin Gene Candidates from Transcriptomic Data.

The area of "venomics" has recently emerged as a growing field using combined transcriptomic and proteomic datasets to characterize toxin diversity in a variety of venomous taxa. Here we present Venomix, a bioinformatic pipeline written in the programming languages Python and R that follows widely accepted procedures for identifying and characterizing toxin-like genes from transcriptomic datasets. Venomix provides the user with several informative output files that can be used to characterize the potential function of these candidate toxins, compare relevant expression level values across toxin-gene candidates, evaluate amino acid conservation among functionally important residues in sequence alignments, and taxonomic and functional information in combination with tree reconstructions to further evaluate toxin gene candidates. We use Venomix to characterize the toxin-like diversity from venom gland transcriptomes for a cone snail (*Chonus sponsalis*), scorpion (*Urodacus yaschenkoi*), snake (*Echis coloratus*) and ant (*Tetramorium bicarinatum*). With the exception of *T. bicarinatum* the toxin diversity for each of these species were previously evaluated using lineage specific toxin gene datasets. Venomix expands beyond these lineage specific predictions identifying new candidate toxin groups and genes, identifying up to five times more toxin candidates when compared to the original study. Venomix quickly sorts, screens, and categorizes toxin-like transcripts from transcriptomic data, enabling researchers to focus on other aspects of toxin characterization beyond simply identification. Venomix is a python package available at: https://bitbucket.org/JasonMacrander/Venomix/ and is in a ready to use downloadable package.

112-2 MACRANDER, J*; SACHKOVA, MY; MORAN, Y; REITZEL, AM; Univ. of North Carolina at Charlotte, Hebrew University of Jerusalem; *jmacrand@uncc.edu*

The starlet sea anemone (Nematostella vectensis) as an emerging model organism for venom studies.

The starlet sea anemone, *Nematostella vectensis*, is an estuarine species with broad distribution across the Atlantic coast of North America. Throughout their distribution N. vectensis are commonly found alongside a relatively homogeneous biological communities (potential predators and prey) and are subjected to variable abiotic stressors depending on their location (temperature, salinity, and UV). We are currently using *N. vectensis* as a model to understand how biotic and abiotic factors influence their overall venom diversity. We are evaluating this diversity at the cellular, individual, and population level as it relates to toxin gene expression, diversity across toxin gene families, and potential change in toxin function in *N. vectensis*. We show that *N. vectensis* are equipped with a diverse arrangement of toxins at different life history stages and across cell type, with some toxins exhibiting regional sequence diversity. Our combined MiSeq, n-counter, and qPCR approaches show that there is little sequence variation with regards to toxin expression across most toxin types as it relates to variable abiotic stressors. We also show that as adults, *N. vectensis* can defend themselves against grass shrimp (*Palaemonestes pugio*) or killifish (*Fundulus heteroclitus*), however, during early embryogenesis and developmental stages *N. vectensis* may be prey for both species. Although the toxin gene assemblage of *N. vectensis* is incredibly diverse, a single neurotoxin gene (Nv1) appears to be the most bioactive peptide when assayed across potential predators or prey throughout their distribution, which is likely the reason behind its conservation across multiple gene copies within the genome.

91-1 MADELAIRE, CB*; CASSETTARI, BO; GOMES, FR; University of São Paulo; *cmadelaire@yahoo.com.br*

Immunomodulation by testosterone and corticosterone in toads: experimental evidences from transdermal application

Testosterone (T) and corticosterone (CORT) are steroids that play important roles in vertebrate reproduction and display complex immunomodulatory function that can affect survival. We investigated the immune consequences of experimental acute elevation of T and CORT in *Rhinella jimi* toads during reproductive season. Due to abnormal T plasma levels, the T transdermal treatment increase androgens to levels compare to the dry period. This resulted in a decrease of the swelling response to the PHA challenge, which is consistent to previous results found for this species in the wild. Additionally, T transdermal application did not display any effect on bacterial killing ability of the plasma (BKA). CORT treatment lead to a more quick response to PHA challenge, but did not affects PHA swelling response or BKA. Although, after treatment individuals displaying higher CORT plasma levels basal and 1h after treatment lowered their BKA response 1h and 10h after treatment, evidencing the effects of high CORT plasma levels in the immune function mediated by complement system proteins. These results indicate that lower levels of androgens suppress inflammatory response; acute doses of CORT increase immune efficiency and high doses of CORT could be immunossupressive to complement system.

P1-244 MADELAIRE, CB*; LAMADRID-FERIS, F; SILVA, DPN; TITON, SCM; TITON JR, B; GOMES, FR; Univ. of São Paulo; *cmadelaire@yahoo.com.br*

How Corticosterone Treatment Affect Wound Healing in the American

During the reproductive season, anuran males call to attract females for mating. This activity result in transient increase of corticosterone (CORT) plasma levels in order to recruit energy stores to sustain this energetically expensive activity. Additionally, under stressful situations that last for extended periods of time, such as food shortage, habitat fragmentation, and pollution, the plasma CORT levels can chronically increase. Acute and chronic elevation of CORT can modulate immune response, affecting how individuals deal with pathogens and injuries. Acute CORT levels are often associated with immunoenhancing effects while chronically elevated levels of CORT is considered immunosuppressive. The objective of this study is to understand how chronic and acute elevation of CORT plasma levels affect wound healing, an integrative immune response, in the American Bullfrog during their reproductive season. Forty males of were bought from a commercial farm and acclimated for seven days in individual plastic boxes, at the University of Sao Paulo, São Paulo, Brazil. Thereafter, individuals were divided into 4 groups: 1) Placebo, which received sesame oil daily; 2) Acute CORT, which received a daily transdermal CORT application (1.0µg); 3) Operated placebo, which received 3 subcutaneous empty silastic tubes (1 x 0,2 cm each); and 4) Operated chronic CORT, which received 3 subcutaneous silastic tubes filled with powder CORT. After the animals recovered from the surgery of silastic tube implant (7 days), all frogs were punctured in the leg with a biopsy needle. The wound was photographed and measured every 2 days in a stereomicroscopy. Blood samples were collected after acclimation, 6 days after surgery; and 6, 13, and 20 days after the biopsy in order to measure CORT and androgens plasma levels. The wound healing rate will be compared between groups and correlated with CORT plasma levels.

P3-224 MAH, JL*; LEYS, SP; University of Alberta; *jmah@ualberta.ca*

'Neural' Genes in Sponges: RNA-seq of a Sponge Sensory Structure

The nervous system is present in all but two animal phyla - one of them being Porifera, sponges. Sponges have no neurons and yet have organized behavior and finely tuned sensation. Furthermore, sponges have genes involved in the nervous system of other animals (informally called 'neural' genes). Do these genes impart a sensory capacity in sponges and does their presence suggest that the sponge sensory system is homologous to the nervous system? I carried out an RNA-seq study to determine whether candidate 'neural' genes might be differentially upregulated in the osculum, a demonstrated sensory structure that is the excurrent vent of the sponge filtration system. Four candidate 'neural' genes - mGluR, GABAR, Kir and Bsh - were significantly upregulated in sponges with oscula compared to those in which oscula were still developing or in sponge body tissues. While glutamate (L-Glu) and GABA have been shown to trigger and arrest (respectively) sponge contraction behavior, glutamate and GABA receptors themselves may have roles in normal metabolic processes and therefore their upregulation in tissues may reflect differential activity of other activities that occur in the osculum. The data presented suggest that genes involved in the nervous system of bilaterians may not be effective markers for sensory/coordinating systems in sponges. Instead, studying 'neural' genes without the assumption that they hold sensory or coordinating functions may provide a less biased way of investigating sensory-neural origins.

84-5 MAHON, AR*; RESH, CA; GALASKA, MP; Central Michigan University, Lehigh University; *mahon2a@cmich.edu*

Applying 'next generation' genomic tools for investigating aquatic invasive species

Detection of rare species in systems, whether they are threatened and endangered or invasive, relies upon the ability to detect and monitor low densities of these organisms with patchy distributions. This can be particularly challenging in aquatic ecosystems, where even large organisms can be difficult to directly observe or capture. Here in the United States, we have been fighting this battle with a number of species, including non-native fishes and invertebrates throughout the Laurentian Great Lakes ecosystem. Traditional sampling methods have proven to only be effective in a narrow range of habitats, principally shallow water with slow water velocities, or there is moderate to high visibility. Additionally, monitoring established populations of species and determining their population structure, origin, and size at low densities has proven difficult. Genetic and genomic methods have the potential to overcome many of the constraints posed by traditional aquatic monitoring and detection gear. However, despite the promise of DNA-based monitoring methods, the adoption of these tools and their acceptance in decision-making frameworks remains challenging. The current status of DNA-based tools for aquatic invasive species monitoring in U.S. and the impediments to their effective translation into management contexts will be discussed. Potential sources of uncertainty associated with molecular technologies, possibilities for limiting that uncertainty, and the future use of these tools for invasive species surveillance in North American waters will be presented.

70-2 MAIA, A*; HELLWIG, M; Eastern Illinois University, University of Rhode Island; *amresendedamaia@eiu.edu*

Median Fin Function in Juvenile Pallid Sturgeon

Fin evolution has allowed for the diversification of fish morphology and subsequent exploration of new habitats. Basal bony fishes have elongated body shapes where paired fins contribute little to thrust. Instead caudal fin and body undulation are the main propellers for these species, although the diversity of dorsal and anal fin shapes seems to indicate a functional role of all the median fins in swimming. Sturgeons are unique in the retention of the notochord in the upper lobe of the caudal fin, which is even more pronounced and elongated in juvenile individuals. We focus on captive bred juvenile pallid sturgeon, an endangered species endemic to the basins of the Missouri and lower Mississippi, to examined median fin function during steady swim in a flow tank using high speed videography and PIV. Our kinematic data show that sturgeon undulate the dorsal and anal fins slightly out of phase with each other, reflecting the dorsal fin's slightly anterior position in respect to the anal fin. These two fins also move with a considerable phase shift to the caudal fin. In terms of lateral displacement, as expected, the lower lobe of the caudal fin has the highest range of motion, almost double that of the dorsal fin. Considering their similar sizes, the higher range of motion of the anal fin in comparison to the dorsal fin is rather surprising. PIV data show evidence of vorticity indicative of thrust generation behind the dorsal fin that is likely to interact with the tail. It also seems to suggest that the elongated upper lobe functions as a trailing edge for vortex redirection. Understanding how endangered species interact with their habitat can aid in effective conservation efforts. Furthermore this study supports the relevance of median fin function not solely explained by the caudal fin and supports the diversification of fin shape with evolutionary implications.

74-4 MAIE, T*; GIUSTINIANI, B; CHRISTY, R; Lynchburg College; *maie.t@lynchburg.edu*
Adhesive Performance of the Pelvic Sucker in a Waterfall-Climbing Gobiid, Sicyopterus japonicus
Sicyopterus japonicus are a species of waterfall-climbing goby fish indigenous to Japan. While developing into adults from a post-larval stage, the fish migrates from the ocean to freshwater rivers and streams. During migration, the fish climbs waterfalls by using alternating motions of suctions by the mouth and fused pelvic fins (pelvic sucker) generating pressure differential that allows adhesion on the rock surface. This suction pressure was recorded by having *S. japonicus* individuals climbing on the artificial waterfall with a pressure transducer installed in its climbing surface. In addition, the suction force was calculated by taking the area of the pelvic fins into account. *S. japonicus* produced the force for adhesion up to 4.3 times greater than their body weight against gravity. During the experiment, some *S. japonicus* individuals showed gradual reduction in suction force for adhesion while staying stationary on the climbing surface, indicating the fish experiences some levels of muscle fatigue, although the absolute minimum force produced was still above the theoretical minimum force requirement. In addition, scaling patterns of the suction force as well as muscle fatigue in relation to body size of the fish indicate ontogenetic changes in functional performance of the locomotor muscles.

15-4 MAJORIS, J.E.*; D'ALOIA, C.C.; FRANCIS, R.K.; BUSTON, P.M.; Boston University, Boston, Woods Hole Oceanographic Institute, Woods Hole; *jmajoris@bu.edu*
Differential persistence favors habitat preferences that determine the distribution of a reef fish
A central focus of population ecology is understanding what factors explain the distribution and abundance of organisms within their range. This is a key issue in marine systems, where many organisms produce dispersive larvae that develop offshore before returning to settle on benthic habitat. We investigated the distribution of the neon goby, *Elacatinus lori*, on sponge habitat and evaluated whether variation in the persistence of recently settled individuals (i.e., settlers) among different sponge types can result in habitat preferences and establish their observed distribution. We found that *E. lori* settlers were more likely to occur on large yellow tube sponges (*Aplysina fistularis*) than on small yellow sponges or brown tube sponges (*Agelas conifera*). An experiment seeding settlers onto multiple species and sizes of sponge habitat revealed that settlers persist longer on large yellow sponges than on small yellow sponges or brown sponges. Habitat preference experiments also indicated that settlers prefer large yellow sponges over small yellow sponges or brown sponges. Settlers achieved these preference behaviors using visual, but not chemical, cues. Finally, new settlers arriving from the water column were more likely to occur on large yellow sponges than on small yellow sponges or brown sponges, indicating that the observed habitat preferences existed independent of prior experience. These results support the hypothesis that *E. lori* have evolved behavioral preferences for sponge habitats that will maximize their post-settlement persistence, and that decisions at settlement will shape the population level pattern of settler distribution on coral reefs.

135-2 MALINGEN, SA*; CASS, JA; DANIEL, TL; Univ. of Washington; *danielt@uw.edu*
Viscous shearing in the sarcomere
Cells interact dynamically with their environment, often altering their structure in response to stimuli. Architectural changes within cells occur in a (generally) small fluid filled environment, where viscous forces overwhelm inertia. Within muscle, the sliding filament hypothesis has described the cyclic architectural changes that occur within the sarcomere in order to accomplish large scale cellular, and ultimately, muscular contraction. Each sarcomere is percolated by cytoplasm, and it remains unknown how this fluid impacts muscle function as the thick and thin filaments slide past one another during contractions. We hypothesize that viscous shear forces between cytoplasm and moving filaments results in an energy expense that has not been quantified. To understand forces and energetics at this small, low Reynolds number scale, we used the singularity method to simulate Stokes flow in a lattice of thick and thin filaments. Using this model, we estimate that the viscous drag force on a single thick filament in the sarcomere half space to be between 2.5 and 25 e-3 pN, depending on the cytoplasm's viscosity. For an entire sarcomere consisting of about 500 thick filaments and 3000 thin filaments we estimate the total rate of energy dissipation resulting from this viscous force to be between 175 and 1750 ATP per second. Our results suggest that viscous shearing in the sarcomere can represent an important avenue of energy dissipation.

P3-89 MALMBORG, AG*; DAVIS, JE; JEANSONNE-MOORE, E; MONCEAUX, C; Radford University; *amalmborg@radford.edu*
Endocrine Disrupting Chemicals in Amazonian Waterways
Though the Amazon rainforest is one of the most biodiverse regions on that planet, several species are being put at risk due to the introduction of endocrine disrupting chemicals (EDCs). EDCs are exogenous agents that have been known to impact species' physiology in various ways. Identifying chemicals that are present in rainforest watersheds is critical in understanding and assessing environmental health. This study focuses on estrogen mimics and disruptors that can be found as either natural or synthetic compounds and have the potential to alter endocrine function. Explored in this study are various locations within the Las Piedras watershed in the Peruvian Amazon to determine exposures and potencies of chemicals across disturbed gradients. Sampling ranged from main waterways with presumably high anthropogenic influence to pristine aquatic ecosystems within the jungle. Thirty-eight samples were analyzed using HPLC and mass spectroscopy in efforts to identify the type of disruption and sources of introduction.

P1-180 MALMBORG, A*; GUISE, E; O'BRIEN, S; Radford University, University of California- Davis;
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The Developmental Effects of Trenbolone on Reproductive Physiology in Gambusia holbrooki
The molecule trenbolone is an anabolic steroid commonly used by cattle farmers as a growth promoter. Trenbolone acts as a testosterone agonist but has a greater binding affinity than testosterone, giving it a greater potential to alter species' physiology (Orlando 2004). The potency of the molecule puts homeostasis and reproductive health of exposed individuals at risk. Previous studies conducted in the Radford University Ecophysiology Lab showed masculinization of matured *Gambusia holbrooki* (mosquitofish) (Guise, 2016). Here, we conducted a developmental study using *Gambusia holbrooki* fry to assess the influence trenbolone has on maturation and reproductive development by administering ecologically relevant doses. Fish morphology was analyzed, specifically looking for alternations to sex characteristics to identify possible reproductive abnormalities.

P1-274 MALUL, D*; SHAVIT, U; HOLZMAN, R; Technion, Tel Aviv University; *malolds@campus.technion.ac.il*
Why do coral tentacles oscillate with a phase shift with respect to the ambient flow?
Sessile stony corals rely on their tentacles to absorb essential nutrients from the water around them. For many corals, the tentacles are the only body organ that can move, and the tentacles are known to modify their morphology when the flow or lighting conditions change. Despite the central role of the tentacles, their behavior and the way they function mechanically is poorly understood. Using high speed photography and PIV measurements we recorded the tentacle movement of *Dipsastraea favus* both *in-situ* and in a standing wave laboratory flume. Under oscillating flow conditions, we observed that tentacles oscillate with a phase shift with respect to the ambient flow and pressure fields, i.e. the tentacles change their direction prior to the change in the flow. This observation suggested that the tentacles have elastic properties, and raised the hypothesis that these observed properties are a result of an evolutionary adaptation to increase mass transfer rates. To test this hypothesis, we modelled the tentacle as a torsion spring-damper-mass system, used our PIV measurements to calculate the forces exerted on the tentacles, and estimated the spring and damping coefficients as a proxy of the tentacle mechanical properties. This framework will enable us to numerically calculate mass transfer rates of observed and simulated tentacles for a range of mechanical properties. The results will then be used to test the hypothesis and evaluate the potential role of the tentacle mechanical properties and their influence on photosynthesis, prey capture and nutrients supply.

22-6 MAMIYA, A; TUTHILL, JC*; University of Washington;
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The neural code for leg proprioception in Drosophila
Proprioception, the sense of self-movement and body position, is critical for the effective control of behavior. In the absence of proprioceptive feedback, animals are unable to maintain limb posture or coordinate fine-scale movements of the arms and legs. However, despite the importance of proprioception to the control of movement in all animals, little is known about the neural computations that underlie limb proprioception in any animal. We developed new methods to record from proprioceptive neural circuits in the fruit fly, *Drosophila*. Each fly leg contains ~135 proprioceptive chordotonal neurons positioned at the joint between the femur and the tibia. We used *in vivo* 2-photon calcium imaging to record calcium sigansl from the axons of this proprioceptor population while manipulating leg position and movement with a magnetic control system. With unsupervised clustering methods, we identified anatomically distinct subpopulations of proprioceptor neurons that encode specific kinematic variables such as leg position, velocity, and direction. Imaging from more specific genetic driver lines, we found that single proprioceptor neurons are sharply tuned for combinations of these variables. We then identified two populations of second-order neurons that process sensory information from leg proprioceptors. Targeted electrophysiological recordings revealed that these two populations are specialized for encoding leg position and directional movement. Overall, our results illustrate how proprioception of a single leg joint is encoded by a diverse population of mechanosensory neurons. Narrowly tuned proprioceptive signals converge onto central pathways that separately represent leg movement and position. This circuit architecture may help to reduce sensory noise while minimizing delays in neural processing. Speed and robustness are critical for feedback control of the limbs during locomotion.

P3-177 MANAFZADEH, AR; Brown University;
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Post-hatching development of hind limb articular morphology in the common quail
Articular geometry is thought to be the primary determinant of joint mobility. However, ontogenetic changes in avian articular morphology remain largely unknown, preventing tests of form-function relationships in developing avian limb joints. Here I present a dataset comprising post-hatching changes in hind limb articular morphology for a representative precocial ground bird, the common quail (*Coturnix coturnix*). Dissections of quail hind limbs were conducted at five post-hatching age stages to identify ontogenetic changes in joint hard and soft tissues, with particular focus on the appearance of the hip, knee, and ankle joint capsules. Each specimen was then disarticulated and µCT scanned, and differential geometry was applied to articular regions to quantify differences in ossification and 3-D articular shape. Joint capsule ligaments are already present in day-old quail, but become more clearly demarcated in older individuals. Additionally, throughout development, condyles at the knee and ankle become more ossified and strongly defined, changing significantly in their shape and relative size. At each hind limb joint, the coupled changes in mating articular surfaces appear to increase joint congruence. These data suggest that range-of-motion at avian hind limb joints should decrease throughout development, especially in abduction-adduction. Future work will test this hypothesis using cadaveric and living birds to determine if articular morphology is a strong predictor of avian appendicular joint mobility.

P2-115 MANAHAN, DN*; SIMISON, WB; RUSSACK, J; HENDERSON, JB; Univ. of Southern California, California Acad. of Sciences; *dmanahan@usc.edu*

De novo genome assembly and annotation of the red-eared slider (Reptilia: Emydidae: Trachemys): Advancing our understanding of hybridization and introgression

The advent of globalism has been tied to an increase in the spread of destructive invasive species across continents. Among the most prominent of these is *Trachemys scripta elegans*, commonly known as the red-eared slider. This turtle species is native to slow-moving freshwater ecosystems between Alabama and Northeastern Mexico but its involvement in the pet trade has distributed these turtles all over North America and Eurasia, consequently outcompeting native species. A current study by Dr. Brian Simison et al. uncovered a population of *T. s. elegans* in the Pecos River of Texas that exhibits introgression from *Trachemys gaigeae*. This evidence of hybridization opens up the possibility that *T. s. elegans* acquires adaptive genes from native *T. gaigeae* populations, which may help explain the expansion of *T. s. elegans* into an ecosystem unlike that of their native swamps. However, before more thorough population genomic approaches can be used to assess the validity of this hypothesis, a reference genome of *T. s. elegans* is required. In this study, I drafted several *de novo* genome assemblies for *T. s. elegans* and identified the presence and location of over 300 *T. s. elegans* genes in these data. The quality of this draft could be further improved by acquisition of more short-read sequencing data to increase genome coverage. Current efforts to improve assembly quality include the computational compilation of current assemblies. This contribution to *Trachemys* population genomics helps provide fundamental insights into the relationship between genomes and their expression into selectable traits, which are important concepts in understanding the mechanisms behind speciation and hybridization.

P2-274 MANCHESTER, CW*; GRAY, JR; University of Saskatchewan; *cody.manchester@usask.ca*

Response of a locust motion sensitive neuron, flight muscle activity and wing asymmetry during flight steering

Flying animals display a variety of adaptive behaviours to avoid predators and collisions with conspecifics during flight. The locust Descending Contralateral Movement Detector (DCMD) is a well characterized small-field motion-sensitive visual neuron that responds with an increased firing rate that peaks near the time of collision (TOC) of an approaching object. Increasing stimulus complexity (number and shape of objects or object trajectory changes) affects the amplitude and temporal properties of the DCMD response profile, whereas flow fields generally evoke narrower response profiles. This is the first experiment to examine DCMD responses during flight steering. Preliminary data show that, compared to a non-flying condition, DCMD in flying locusts responded to a head-on approach (0°) with a narrower response profile and lower peak firing rate whereas an approach from 45° evoked a later peak. Previously described DCMD bursting occurred in non-flying and flying locusts, suggesting that bursting is critical for coding object approach. Bursts also showed an earlier increase in intraburst firing rate during a 45° loom, compared to an approach from 0°. This indicates that bursting responses change with respect to stimulus direction and that bursts are an important component of coding to coordinate motor output during collision avoidance behaviour. EMGs from forwing left and right steering depressor muscles (m97) revealed earlier Lm97 activation, indicating a left turn, when presented with an object approaching from the right. High speed video of the forewings demonstrated wing asymmetry in which the left wing depressed sooner than the right wing. These results provide insights into general principles of corrdinated flight steering.

S11-4 MANDER, L; The Open University; *luke.mander@open.ac.uk*

Modern and Ancient Plant Biodiversity: what use are Pollen Grains?

Plants produce huge numbers of pollen grains as part of their reproductive cycle. Pollen grains are tough and widely dispersed and they also fossilise readily in a wide variety of environments. Consequently, pollen grains are widely used as an empirical record of plant evolution. In this talk I begin by outlining a few examples where pollen grains have provided data on plant biodiversity and then focus on the tropics, which harbour extraordinarily high levels of flowering plant diversity. This diversity is expressed in the morphology of flowering plant pollen grains, which are by characterised by striking variety in their shape and patterning. I approach this vast morphological diversity from the perspective of enumerative combinatorics. This involves generating pollen morphotypes by algorithmically combining character states and enumerating the results of these combinations to establish a raw un-ordinated morphospace for flowering plant pollen. I map the pollen grains of 1,008 species of neotropical angiosperms onto this morphospace, which facilitates the comparison of forms that exist in nature and forms that do not. This mapping highlights that neotropical rainforests represent an enormous reservoir of morphological diversity, but whether the patterns of morphospace occupation can be interpreted in terms of an adaptive landscape is unclear. The large number of discrete character combinations that arises from the morphological complexity of pollen grains presents a data visualisation challenge, and I have experimented with ideas ranging from multipartite graphs, to "imagespaces" in which each pixel represents a unique combination of discrete characters. The approaches I discuss here have been developed to quantify the diversity of plant life as recorded by pollen grains, but could be employed in any situation where some aspect of organismal form can be captured by discrete characters.

72-6 MANGALAM, M; University of Georgia; *madhur.mangalam@uga.edu*

Haptic Perception in Motor Control, at Land, in Water, in Air, and in Space, of a Fish's Fin, a Flamingo's Neck, a Monkey's Tail, a Snake's Spine, and a Bat's Wing

Deft coordination of body movement in animals exploits the capabilities of the level of synergies, a level orchestrated through haptic perception. Here, my goal is to exemplify how animals' attunement to perceptual invariants underlies haptic perception in motor control. Fourteen participants wielded twelve different occluded objects held in air or immersed in water and reported their perceived lengths. Each object consisted of a rod of specific density with specific number of stacked steel rings attached at a specific location along its length. A single-valued function of the rotational inertia, *I* —an invariant mechanical property—predicted their perceived lengths in both air and water, and the perceived lengths remained invariant across the two media. It is known that lowering muscle temperature slows the development and transmission of muscular force and diminishes muscle stretch-reflex sensitivity. I hypothesized that if the haptic information acquired during perception through dynamic touch is derived from muscle activity, changes in mechanical properties of muscles should result in altered magnitudes of haptic stimulation. Twelve participants wielded the occluded objects and reported their perceived lengths at three different muscle temperatures. The perceived lengths of the objects were longer and the relationship between I and the perceived lengths was stronger at a higher muscle temperature. My results imply a direct and reciprocal relationship between action and perception arbitrated through smart perceptual devices attuned to extract perceptual invariants from their environment. I discuss how the concept of perceptual invariants provides a principled approach to haptic perception in motor control, at land, in water, in air, and in space, of a fish's fin, a flamingo's neck, a monkey's tail, a snake's spine, and a bat's wing.

P1-287 MANGALAM, M*; FRAGASZY, DM; University of Georgia; *madhur.mangalam@uga.edu*
Joint Synergies in Nut Cracking in Wild Bearded Capuchin Monkeys
A few wild populations of bearded capuchin monkeys, *Sapajus libidinosus* use stones and wood pieces in their natural form for pounding palm nuts and other encased food. In the present study, we investigated the biomechanical strategies employed by wild monkeys at Fazenda Boa Vista, Piauí, Brazil to coordinate their movement to control heavy hammers while cracking nuts. We performed the UCM analysis on joint angle movements of BC monkeys of different body mass striking nuts with hammers of different mass. To crack open a nut, monkeys must strike it with a hammer with adequate value of the hammer's kinetic energy at impact within a range of the point and angle of impact. However, the monkeys kept the strike's amplitude and the hammer's velocity at impact, but not the hammer's kinetic energy at impact unchanged with respect to hammer mass. Surprisingly, the monkeys showed very small variability in the location of the hammer's center of mass, although the latter appeared to increase with hammer mass. UCM analysis revealed that joint angle variability was greater in the controlled subspace compared to the uncontrolled subspace. In other words, well-defined joint synergies characterized the striking movements of the monkeys. Body mass and hammer mass appeared to influence the strength of the synergy, that is, the ratio of joint angle variability in the controlled and uncontrolled subspace. These results suggest that wild bearded capuchin monkeys have discovered unique motor solutions to cracking nuts through joint synergies that allow them to control the trajectory of heavy hammers. We discuss these results in the light of orgasmic, environmental, and task constraints on monkeys' striking movements.

P3-200 MANNA, T.J.*; TONG, L.; BáN, M.; AIDALA, Z.; MOSKáT, C.; HAUBER, M.E.; CUNY Hunter College and the Graduate Center, New York, University of Debrecen, Debrecen, Bloomfield College, Bloomfield, Eötvös Loránd University, Budapest, University of Illinois, Urbana-Champaign; *tommyjmanna@gmail.com*
Cognitive Interference Reduces Egg Rejection Accuracy in Cases of Multiple Parasitism
A host which has been targeted by an avian brood parasite can recover most of its potential fitness loss by ejecting the foreign egg(s) or offspring from its nest. The propensity for some hosts to engage in this behavior has put selective pressure on their parasites to evolve mimetic eggshells of the host's color and maculation. In turn, hosts have counter-evolved increasingly more sophisticated detection methods such as narrowing visual discrimination thresholds or even using non egg-specific cues. However, multiple sensory and cognitive mechanisms acting simultaneously could theoretically interfere with one another and ultimately decrease egg rejection accuracy. Through an artificial parasitism protocol, we tested a host of the common cuckoo *Cuculus canorus*, the great reed warbler *Acrocephalus arundinaceus's* response to 1, 3, or 5 simulated foreign eggs of varying color and uniformity. Using reflectance spectra of egg background coloration and avian perceptual modeling, we then estimated the sensory thresholds of this host. Rejection rates were positively related to the perceptual distance between own and foreign eggs in the nests in all treatments, but rejection thresholds were more permissive (error prone) both with greater proportions of foreign eggs and when the suite of foreign eggs were perceptually more variable within the nest. These results suggest that the evolution of host recognition of parasite mimicry has multiple trajectories regarding both the specific sensory and cognitive defense mechanisms underlying their recognition thresholds, and their vulnerability to parasitic counterstrategies.

S8-4 MANNI, L*; ANSELMI, C; PENNATI, R; MERCURIO, S; GASPARINI, F; Department of Biology, University of Padova, Italy, Department of Environmental Science and Policy, University of Milan, Italy, Department of Environmental Science and Policy, University of Milan, Italy; *lucia.manni@unipd.it*
Development and Function of Secondary Mechanoreceptor Cells in Tunicates
The presence of secondary sensory cells in tunicates was firstly signaled in 2003, when a new mechanoreceptor organ, the coronal organ, was described in the oral siphon of the ascidian *Botryllus schlosseri*. As tunicates are considered the sister group of vertebrates, coronal cells were immediately seen as the best candidate to address the controversial issue of hair cell evolution in chordates. Since then, the study of these cells has been active. Now, we know that the coronal organ derives from an anterior proto-placode, an ectodermal thickening expressing vertebrate placodal genes. The organ is considered a plesiomorphic feature of the taxon, as all tunicates analyzed so far possess it. Its sensory cells exhibit an apical bundle bearing cilia and microvilli (or stereovilli) and lack an axonal prolongation. Coronal cells check particle entrance into the oral siphon during filtering activity: in case of necessity, they evoke the typical "squirting reaction", *i.e.* the rapid body muscle contraction that is used to eject dangerous particles from the branchial basket. Tunicate coronal cells share with vertebrate hair cells some developmental genes and neurotransmitters, the complexity of synaptic connectivity, and the susceptibility to ototoxic drugs. Some other features result specific of coronal cells, such as the absence of an ordinated pattern of stereovilli and mechanoelectrical transduction based on tip-links, or the ability to divide mitotically, rendering them a unique chordate sensory system.

57-6 MANSUR, Z*; OWENS, C; BURKS, RL; HAYES, KA; Howard University, Washington, DC , Howard University, Washington, DC, Southwestern University, Georgetown, TX, National Museum of Natural History, Washington, DC; *zahra.mansur@bison.howard.edu*
Multiple Paternity in Pomacea canaliculata (Ampullariidae) from the La Plata Basin, Uruguay
Multiple paternity, the fertilization of one clutch of eggs by sperm from multiple partners, can have substantial effects on population structure and genetic diversity. High levels of genetic diversity are thought to be important for the success of small, founding populations, such as those of *Pomacea canaliculata*, which have become major invasive pests outside of their native range. To better understand the role that multiple paternity may play in population dynamics of *P. canaliculata*, ten egg clutches were collected from their native range in Maldonado, Uruguay. Species identification based on mitochondrial COI sequences revealed 9 of the clutches to be *P. canaliculata* and the remaining clutch to be an undescribed *Pomacea* species. Initial analysis of four microsatellite loci from >60 individuals in each of two *P. canaliculata* clutches revealed possible null alleles and/or genotyping errors with some individuals. Removal of these individuals resulted in a dataset with 47 and 53 individuals for the two clutches, with 2-7 alleles at each of the four loci. Paternity analyses indicated the presence of at least two fathers for one clutch, and three in the other. These data confirm early accounts of multiple paternity in *P. canaliculata*, and highlight the reproductive strategies that this species employs as one of the most successful invasive species globally. Microsatellite analysis of all ten clutches will add further insights into how *P. canaliculata* overcomes the genetic bottlenecks associated with introduction to non-native habitats, and the role that multiple paternity may play in evolution of ampullariids within their native ranges.

P2-70 MARESH, JL*; CORL, A; COSTA, DP; LAW, CJ; West Chester University, Univ. of California, Berkeley, Univ. of California, Santa Cruz, Univ. of California, Santa Cruz; *jmaresh@wcupa.edu*

Predictors of Metabolic Rates in Aquatic Mammals

All biological activities depend on metabolic energy, and thus understanding why metabolic rates vary across species is of fundamental importance in understanding how animals work. For mammals, it is generally understood that metabolic rates are elevated in marine species despite considerable taxonomic and ecological diversity. There are two prevailing, non-mutually exclusive hypotheses to explain this phenomenon: as an adaptation for aquatic endothermy and/or as a consequence of the high costs of carnivory. In this study, we used a phylogenetic comparative approach to examine the effects of environment (aquatic vs. terrestrial) and diet (carnivory vs. non-carnivory) on the scaling patterns of metabolic rates in mammals. To test for differences between groups, we performed phylogenetic generalized least-squares regressions and analysis of covariance on the resting and field metabolic rates of 537 and 90 eutherian mammal species, respectively. We also performed ancestral state reconstructions to map the evolution of metabolic rates across all mammals. We show that while resting metabolism is elevated in some marine taxa, it is not unique to the aquatic environment nor is it a shared characteristic of all marine species. Our analyses also indicate that the field metabolic rates of marine mammals are comparable to those of other mammals both on average as well as in their variability. Additionally, we found that the field metabolic rates of marine mammals are indistinguishable from those of terrestrial carnivorans. Together, these results suggest that marine mammals are not exceptional in their metabolic energy needs, are metabolically diverse, and that carnivory may be more important than environment as a predictor of metabolic adaptations in aquatic mammals.

52-6 MARKELLO, KM*; MOOI, R; California Academy of Sciences, San Francisco; *kmarkello@gmail.com*

Hooked on Feather Stars: Using novel characters and molecular barcodes to uncover crinoid diversity in the Philippines

Recent surveys indicate that the Verde Island Passage (VIP) in the Philippines has the highest marine biodiversity in the world. One of several phyla that exemplify this remarkable species richness is the Echinodermata, comprising asteroids, ophiuroids, echinoids, holothuroids, and crinoids. The latter are represented in shallow water by the comatulids (feather stars) and are arguably the least known of the phylum in terms of diversity, systematics, and distribution. However, comatulids are important suspension-feeding members of the reef community. There are no baseline studies that attempt to assess diversity of comatulids in the VIP, and without these analyses, it will be impossible to measure impacts of anthropogenic changes on this crucial constituent of the reef ecosystem. As part of a program of collaborative biodiversity assessments conducted by the California Academy of Sciences and its Philippine partner institutions, we collected comatulid crinoids from reefs throughout the VIP. Comatulids are notoriously difficult to identify using morphology alone, so we integrated molecular and morphological techniques to distinguish taxa. We constructed a barcode library using COI to differentiate taxonomic units. Using SEM, we discovered a novel morphological character, pinnular hooks, that can be used to distinguish taxa. Current results suggest that comatulid species richness in the Verde Island Passage will exceed any previous estimates for other locations in the Indo-Pacific region, if not the world. Our integrative approach will facilitate future efforts to identify crinoids in the Philippines as well as aid in our attempts to develop an accurate estimate of their diversity in the VIP.

S7-10 MARQUARDT, Shauna; U.S. Fish and Wildlife Service; *shauna_marquardt@fws.gov*

On the Cutting Edge of Research to Conserve At-Risk Species

Charged with the management of fish, wildlife, plants, and their habitats for the benefit of the public, the U.S. Fish and Wildlife Service strives for scientific excellence to inform its practices and approaches to conservation. Though the scientific expertise held within the Service is broad, it is not possible to maintain subject matter experts in all genera of science and technology. In the face of legal challenges and to facilitate data-based decisions and policy, the Service participates in strategic partnerships with academic and non-governmental entities. This paper focuses on cutting-edge research derived from diverse, multi-disciplinary research collaboratives formed to address information gaps in conservation and recovery programs for federally listed species and species of concern. Using case studies of recent and on-going research efforts, we trace pathways for initiating coordination with Service scientists, developing research teams, and securing financial and logistical support for priority projects. The paper culminates with examples that illustrate how the Service incorporates collaboratively generated data and tools.

75-1 MARSHALL, S.K.*; SPAINHOWER, K.B.; BUTCHER, M.T.; Youngstown State Univ.; *skmarshall@student.ysu.edu*

Post-cranial morphology in the Xenarthra: Hind limb structure and function

Anteaters, armadillos, and sloths each have distinctive body plans, yet they are all members of the basal superorder Xenarthra due in part to a number of shared anatomical characteristics about their skull and spine. Divergence in their morphology is associated with the functional habits they exhibit ranging from suspensory locomotion in sloths to fossorial scratch-digging in armadillos. We hypothesize that quantitative differences in hindlimb form will be predictive of the locomotor habits observed among xenarthrans and help to resolve the influences of morphology vs. phylogeny in their present classifications. Comparative analyses were performed on a sample of N=45 skeletal specimens comprising 14 species. A total of 24 functional indices were calculated from 45 raw linear measurements of bone length, width, and depth, and these metrics were evaluated using PCA to determine osteological correlates among extant taxa. Preliminary results show that the first two PCs accounted for 54% of the cumulative variance with the greatest separation of genera along PC1. In general, armadillos shared morphospace, and all have robust femora/tibiae, wide epiphyseal condyles, and a broad tibial tuberosity. These characteristics are intermediate in the anteaters, while sloths have longer, more gracile bones with reduced (or absent) bony protuberances. In addition, there was notable separation along PC2 between two-toed and three-toed sloths, where Bradypus is associated with positive values representing shorter limb length but longer hindfoot elements. Future analyses will: evaluate the influence of allometry and mass on the observed trends of post-cranial morphology, identify features that best predict substrate preference/use, and further resolve evolutionary relationships among xenarthrans.

P3-86 MARSHALL, H.*; MITCHELL, T.; SCHWARTZ, T. S.; WARNER, D. ; Department of Biological Sciences, Auburn University, Auburn, Alabama; *hbm0006@auburn.edu*

Multiple Paternity in Anolis sagrei

Multiple mating is a common strategy in many species, and potential benefits include increased genetic diversity of offspring, higher chance of fertilization for females, and greater chances of survival for offspring. While it is well established that both polyandry and sperm storage in lizards occur, we want to determine the extent to which this happens in brown anole lizards (*Anolis sagrei*) under direct competition. Brown anoles lay one egg approximately every 7-10 days through the breeding season. Adult brown anoles from the field (n=110) were housed in groups of either 4 (2M:2F) or 6 (3M:3F) across 23 experimental enclosures and allowed to mate and produce eggs over one breeding season. We use microsatellite markers to genotype the offspring produced and to determine parentage. We are using these data to address the following questions: What is the extent and longevity of sperm storage from field mating prior to the experiment? What is the temporal pattern of multiple paternity across the breeding season in this captive population?

28-3 MARSHALL, KE*; CHAN, BKK; MARSHALL, Katie; University of Oklahoma, Academia Sinica; *kemarshall@ou.edu*

Transcriptomic Responses to Freezing Stress in the Barnacle Semibalanus balanoides

Freeze tolerance is an extreme adaptation that is found broadly across the tree of life, including several animal lineages (both invertebrate and vertebrate) as well as in several plant species. Most studies have focused on insects and plants and relatively little is known about the mechanisms of freeze tolerance in crustaceans. Here we contrast two populations of the circumpolar and intertidal barnacle *Semibalanaus balanoides*, one from the southern margin of its range in British Columbia, Canada, and one from the northern edge of its range in the White Sea, Russia to elucidate potentially novel mechanisms of freeze tolerance in a poorly-understood system. We froze barnacles at -6 °C for two hours, and allowed them to recover at 10 °C in seawater, taking samples both during the freezing stress as well as after 2 h and 26 h of recovery. Using RNA-seq we first produced a transcriptome of 46,613 sequences that excluded all microbial transcripts. We then contrasted gene expression between the two populations at all three time points. Barnacles from British Columbia had a much greater transcriptomic response that continued to increase through all three timepoints, and that was dominated by downregulation of transcription. By contrast, barnacles from the White Sea had approximately equal numbers of up and down regulated transcripts, and had the greatest number of differentially regulated transcripts during the 2 h recovery window. We also found that they had significant upregulation of transcripts associated with glycerol and water transporters, signatures of intense heat shock protein upregulation, as well as potential novel antifreeze proteins. Taken together, our study shows that even short freezing exposures cause lasting changes in gene transcription and that mechanisms of freeze tolerance may be an example of convergent evolution across animal and plant life.

140-2 MARSHALL, CA*; EARLEY, RL; GHALAMBOR, CK; Colorado State University, University of Alabama; *cam13@colostate.edu*

Salinity, Stress, and Metabolism: Integrated physiological correlates of osmoregulation in Trinidadian swamp guppies (Poecilia picta) along a salinity gradient

Euryhaline fish species can deal with a wide range of salinities. However, the extent to which populations may deal with different salinity levels through plasticity versus adaptation remains an underexplored question. Previous work in euryhaline teleosts suggests local adaptation to a given range of salinity, and outside this range, fish exhibit elevated stress responses (e.g. increased oxygen uptake and circulating cortisol levels). However, because circulating plasma cortisol levels and metabolic rates are involved in both osmoregulation and stress responses, the use of such physiological measures to distinguish local adaptation from adaptive plasticity is complicated. Here, we compare populations of Trinidadian swamp guppies, *Poecilia picta*, that are found in adjacent fresh, brackish, and marine habitats, to test if populations are locally adapted to various salinities. We investigated the effects of salinity on field plasma cortisol levels and oxygen consumption in swamp guppies collected from three drainages. In the lab, we tested if these patterns persisted after short- and long-term acclimation to different salinities. In the field, we found circulating cortisol levels were lowest under stable salinity levels (0ppt and 20+ppt) but elevated in sites where salinity fluctuated. Oxygen consumption was highest in the home salinity levels and lowest in "away" salinities over the short-term, and differences among populations were maintained even after long-term acclimation, suggesting populations are locally adapted. Collectively, these results suggest the degree of environmental variability in salinity shapes plastic and evolved physiological responses of populations.

100-2 MARTIN, KS*; KAHRL, AF; IVANOV, BM; JOHNSON, MA; Karolinska Institutet, Stockholm University, Trinity University, Trinity University; *kyle.martin@ki.se*

Copulation rates in anole lizards are correlated with muscle damage

One of the challenges in behavioral ecology is an accurate quantification of relatively rare or cryptic behaviors such as copulation. Behaviors that activate skeletal muscles can lead to adaption such as hypertrophy and fiber type switching. Muscles are also damaged during use in a frequency- and intensity-dependent manner. Muscle damage causes the recruitment of inflammatory cells which remove debris and allows the native tissue to regenerate. When viewing muscles in cross section, muscle damage manifests as disruptions of normal muscle architecture, notably invaded muscle fibers and regions of densely packed cells. In anoles, the retractor penis magnus (RPM) is only activated during copulation. Thus, muscle damage in the RPM should be due to mating, and the extent of damage may indicate the extent of muscle use. We tested the hypothesis that observed copulation rate is positively correlated with RPM muscle damage. We used field observations to determine copulation rates for 27 species of anoles across the southern United States and Caribbean islands. Males from each species were captured and tail muscle tissues were dissected, flash-frozen, cross sectioned, and stained with H and E. We outlined each RPM (total cross-sectional area or CSA) and the damaged tissue (damaged CSA). We calculated a ratio of muscle damage (damaged CSA / total CSA) for each RPM and averaged the two sides to give each animal a single value. We then used phylogenic generalized least squares regression to test for a correlation between the ratio of damage in the RPM to the observed copulation rate in the wild. We found that RPM damage was significantly correlated to copulation rate. Our study suggests that RPM damage can be used as a proxy for estimating copulation rates in anoles, and more generally, that muscle damage may be a proxy for estimating muscle use across species.

P2-65 MARTIN , GG*; STAMNES, S; FIELDS, N; SIDEBOTTOM, R; Occidental College, Los Angeles; *gmartin@oxy.edu*

Hemocyte nodule formation and efficiency in the Vetigastropod, Megathura crenulata

Hemocytes circulate through the open circulatory system of gastropods as non-adhesive cells, which rapidly become adhesive and aggregate as nodules when exposed to foreign materials. The binding and subsequent elimination of microbes by hemocytes is an important part of the innate immune response in mollusks. We address two aspects of this response in the giant keyhole limpet. First, when hemolymph was mixed in vitro with two microbes (*Vibrio fisheri* and *Bacillus subtilis*) there was a rapid decrease in the concentration of both bacteria. In addition, there was a decrease in the number of nodules produced due to growth of individual nodules and the fusion of smaller nodules. Presumably, hemocytes binding to the outer surface of growing nodules continued to collect microbes in circulation. Second, stages in the phagocytosis and degradation of the microbes are described. After five minutes of nodule formation, the aggregates could be readily observed by eye. These nodules were transferred from the hemolymph sample containing bacteria to fresh plasma in which the hemocytes had been removed by centrifugation. The capture, phagocytosis and degradation of the microbes in these nodules is described based on SEM and TEM examination.

S6-9 MARTIN, LB*; FLOCK, T; VITOUSEK, MN; HORMONEBASE CONSORTIUM, ; Univ. South Florida, Cornell U.; *lbmartin@usf.edu*

Vertebrate glucocorticoid regulation varies with introduction history

In several avian and amphibian species, GC regulation varies such that individuals living at range edges maintain different levels in circulation than individuals living at the core of a range. These patterns are thought to arise because GCs can regulate traits important to success at different parts of a range. Here, we queried whether introduction history (i.e., whether a species was native or non-native) and location within the native range (i.e., edge versus core versus the intervening area) predicted baseline and post short-term restraint GC levels. To detect the presence of relationships, we used HormoneBase, a repository of much of the published GC data from wild vertebrates. In birds and reptiles, baseline GCs were lower in non-native than native species, although in the latter group, these effects were more pronounced in females than males. In native species, location of capture within a range also predicted GC regulation. Here though, directionality appeared to vary with taxon and sex such that no clear pattern emerged. Presently, we are assessing to what extent phylogeny (at finer levels) influences our results; many of the non-native data are available for only a few species. Nevertheless, our work further suggests that GC regulation affects the distribution of organisms, perhaps by influencing which individuals survive at the time of introduction.

57-7 MARTIN, CH; University of North Carolina at Chapel Hill; *chmartin@unc.edu*

The cascading effects of divergent performance demands on the evolution of trophic specialists within a Caribbean pupfish radiation

Organismal form is shaped by natural selection through the lens of performance. Here I show that performance demands can also affect all levels of biological organization, from genetic architecture to fitness landscape to mate choice to diversification rate. My lab investigates the rare origins of pupfish adaptive radiation endemic to a single Bahamian island, including a large-jawed scale-eating specialist and a molluscivore with a novel nasal protrusion. Scale-eating exerts substantial performance demands for efficient high-speed strikes to remove small amounts of protein-rich mucus and scales. This results in a wider fitness valley, stronger pre-mating isolation, faster oral jaw diversification rate, and larger-effect genetic architecture underlying increases in jaw size. In contrast, molluscivory requires robust, shorter jaws to feed on non-evasive prey. This low-demand trophic performance results in a shallow, narrow fitness valley, weak pre-mating isolation, moderate jaw diversification rates, and a small-effect genetic architecture underlying shorter jaw lengths. Surprisingly, both specialist trophic morphologies benefited from past introgression of adaptive alleles from the distant Grand Bahama Bank. Thus, the performance demands of highly divergent trophic specialists have cascading effects on biological organization. Despite abundant ecological opportunity, these trophic specialists may have originated from the fortuitous assembly of different pools of standing genetic variation from across the Caribbean.

55-1 MARTIN, BT*; MUNCH, S; HEIN, AM; NOAA/ Univ. of California, Santa Cruz; *benjamin.martin@noaa.gov*

The Automatic Discovery of Ecological Theory from Data

Ecologists have long sought to understand the dynamics of populations and communities by deriving mathematical theory from first principles. This standard theoretical approach differs radically from the data mining methods making their way into ecology from fields like machine learning. Here, we explore whether a data-mining technique known as symbolic regression can bridge these disparate approaches, by automatically discovering dynamical relationships in real ecological data, but expressing those relationships using dynamical equations - the language of theoretical ecology. By applying this technique to three classic demographic time series we found this method rapidly discovers dynamical models that explain most of the variance in all time series. Model predictive ability begins to saturate with increasing model complexity at a surprisingly small number of free parameters and the model occupying the saturation point was precisely the model previously proposed by theoretical ecologists: the logistic growth equation for Paramecium growing in isolation, the Lotka-Volterra predator-prey equations for Paramecium and Didinium in co-culture, and a chaotic stage-structured population model for Tribolium flour beetles. Our findings suggest a powerful new way to merge ecological data analysis and theory development. Furthermore, symbolic regression may have useful applications in organismal biology, for example by reverse engineering ‘behavioral circuits' from time series of animal movements and behaviors.

30-3 MARTINEZ, CM*; MCGEE, MD; WAINWRIGHT, PC; Univ. of California, Davis, Monash University; *cmartinez1207@gmail.com*
Morphological Adaptations for Evasive Prey Capture Result in More Dynamic and Efficient Suction Feeding in Cichlids
Evolution of the feeding apparatus in ray-finned fishes has been dominated by a trend of increased jaw mobility, or kinesis. This research focuses on the relationship between cranial morphology and feeding kinesis in the trophically diverse cichlids of the East African rift lakes, Malawi and Tanganyika. We used geometric morphometrics to quantify feeding kinesis as trajectories of shape change through morphospace. Analyses were based on 326 videos of feeding strikes from 56 cichlid species, recorded at 2,000 frames per second. We evaluated the magnitude of kinesis achieved during strikes and also developed a metric of kinematic efficiency, which is related to the conservation of shape change during feeding. We found that both metrics were significantly related to head shape, where species with larger mouths and elongate heads had more dynamic and efficient strikes than species with stout heads and shorter jaws. These patterns of morphological and kinematic variation were also related to feeding ecology, with increasingly evasive prey types associated with greater kinesis and more motion-efficient strikes. Our results indicate that a tight linkage between cichlid morphological diversity and feeding ecology that is mediated by the functional demands associated with capturing preferred prey.

15-2 MARTING, PR*; WCISLO, WT; PRATT, SC; Arizona State University, Smithsonian Tropical Research Institute; *pmarting@asu.edu*
The effect of colony transplant and resource manipulation on collective personality in an ant-plant mutualism
The symbiosis between *Azteca* ants and *Cecropia* trees is one of the most successful and prominent mutualisms of the neotropics. Plants provide food bodies and nesting cavities for ant colonies that protect the plant from herbivores and encroaching vines. However, some colonies are consistently more aggressive than others in a suite of behavioral traits measured in the field, revealing that colonies themselves have personalities. Plants with more active, aggressive colonies have less leaf damage, suggesting that collective personality has ecologically relevant consequences. What is driving the differences in personality types? I designed an experiment to test whether collective personality is a fixed, inherent property of the colony or influenced by environmental factors. To determine if soil nutrients influences plant resources and colony behavior, I conducted a three-phase experiment where I 1) assessed colony behavior in the field, 2) harvested trees, extracted colonies, and transplanted them into greenhouse plants under differing nutrient treatments, and 3) re-assessed colony behavior 10 months later. Analyses of ant behavior, colony growth, and plant investment are currently underway to determine the persistence of personality and its interaction with plant nutrients. This research is important to our understanding of individual differences in behavior, how they arise, and how can influence other species in their ecosystems.

83-5 MARUYAMA, S*; WEIS, VM; Oregon State University; *maruyash@oregonstate.edu*
The role of symbiont glycans and host immunity in the recolonization of the model cnidarian Aiptasia with heat-stressed Symbiodinium
Warming oceans threaten to wipe out coral reefs around the world by jeopardizing the mutualistic relationship between corals and their intracellular algae. Under environmental stress (often high temperature) corals bleach and lose their algal symbionts. The prevailing model for bleaching suggests that the generation of destructive reactive oxygen species, triggered by a combination of light and heat stress, plays a central role. However, severe bleaching can still occur under heat stress alone in deeper, low light coral reefs, indicating that other mechanisms are involved. Inter-partner glycan-lectin signaling is a pathway in which dysfunction may lead to bleaching. Glycans are sugar molecules on the symbiont cell that are recognized by host lectins during the onset of symbiosis. In vitro manipulation of symbiont glycans results in decreased uptake of symbionts by hosts, and some host lectins are downregulated under heat stress. We hypothesize that heat-induced changes in the algal glycome will reduce symbiont uptake, and that this is caused by the host mounting an immune response against heat stressed symbionts. First, to assess if heat stress reduces symbiont uptake, aposymbiotic *Aiptasia pallida*, a sea anemone that is a globally adopted model system for the study of coral symbiosis, was recolonized at ambient temperature with heat stressed symbionts, *Symbiodinium minutum* (32°C for 3 or 7 days). Results showed decreasing uptake with longer durations of heat stress, and this was not attributable to symbiont mortality. We will also present results on tests assessing the symbiont glycome under heat stress, and tests on host immunity during symbiont uptake by measuring NF-kB expression, a proxy for immune response.

87-1 MASHANOV, V*; KHOURY, M; AMBROSE, A; MASHANOVA, D; ZUEVA, O; University of North Florida, Jacksonville, FL; *vladimir.mashanov@unf.edu*
Neural regeneration in an echinoderm
The brittle star *Ophioderma brevispinum* is an emerging model in regenerative biology. This highly regenerative echinoderm readily autotomizes and grows backs its body appendages called arms. Each arm contains a radial nerve cord (a major component of the central nervous system) and an elaborate system of peripheral nerves. This highly complex nervous system is completely restored in the regenerated arm. The early post-injury phase (day 2-3 post injury) involves dedifferentiation of the neuroepithelium of the radial nerve cord in the vicinity of the autotomy plane. The nervous processes disappear while the remaining glial cells dedifferentiate and re-organize themselves to form a blunt-ended epithelial tube. The cells of the glial tube give rise to new segments of the radial nerve cord in the regenerating arm through extensive cell proliferation. Initially, the regenerating sections of the radial nerve cord are completely devoid of neuronal elements, but as soon as on day 11 post-autotomy the first neuronal progenitors differentiate within the glial tube. They are marked by the expression of the transcription factor Brn1/2/4 and the RNA-binding protein ELAV. At the same time, the regenerating segments of the radial nerve cord start developing their neuropil with axons immunolabeled with neuronal markers, such as synaptotagmin B, acetylated tubulin, and the neuropeptide GFSKLYFamide. The injured radial nerve cord of the brittle star therefore regenerates from its own glial cells, rather from undifferentiated pluripotent progenitors, as was suggested earlier.

104-3 MASLAKOVA, SA*; SCHWARTZ, ML; MOSS, ND; DILLENBURG, B; ROBBINS, K; COLLIN, R; ZATTARA, E; HOWLAND, C; NORENBURG, J; Oregon Institute of Marine Biology, Univ. of Oregon, Univ. of Washington, Tacoma, Smithsonian Tropical Research Institute, Panama, National Museum of Natural History, Smithsonian Institution; *svetlana@uoregon.edu*
Nemertean diversity of Bocas del Toro, Panama
The nemertean fauna of Bocas del Toro, Panama is very poorly known. Two publications report approximately 16 species, two thirds of which are unnamed. Recent DNA-barcoding of nemertean adults and larvae sampled by us over the course of the past 15 years suggests that the actual diversity is at least five times what is reported, with an even greater fraction of undescribed species. Out of 81 putative species, we found 14 only as larvae, 66 only as adults and just one as both larval and adult forms. Little overlap between adult and larval samples suggests that we are still undersampling. Our data suggests that nemertean fauna of Bocas del Toro includes many cryptic species complexes, each containing 2-5 molecular operational taxonomic units. Prevalence of cryptic species and sporadic sampling likely explain the discrepancy between the number of reported species and the actual diversity. Our immediate goal is to formally characterize and describe this diversity, focussing on characters of external appearance of live animals, and DNA-barcodes. Our experience suggests that this information, in addition to geographical and habitat data, allows unambiguous species identification. Eliminating traditional histological examination will dramatically expedite the process of species description — a necessity, given the large amount of undescribed diversity, and the rapid changes of Earth's climate and ecosystems.

P1-263 MASON, T, S*; TILT, L; CIERI, R, L; FARMER, C, G; University of Utah; *13tmason@gmail.com*
The Pulmonary Anatomy of the Grey Parrot (Psittacus erithacus) Studied by Computed Tomography
The anatomy of the bird lung is highly complex and has fascinated scientists for centuries. Although the overall patterns of airflow within the avian lung are well established for major conducting airways, measurements cannot be made in all parts of the lung. Furthermore, aerodynamic mechanisms that give rise to these patterns of flow are not fully understood. Computational fluid dynamics (CFD), a technique which calculates patterns of flow based on the Navier-Stokes equations, may provide insight into patterns of flow where empirical measurements are difficult to make. Furthermore, CFD models can provide insight into the mechanisms underpinning the aerodynamic valves, as well as patterns of flow under different boundary conditions, for example, simulating exercise and panting. A crucial step in developing a CFD model is to faithfully represent this complex anatomy mathematically. The extreme complexity of the avian respiratory system has made this a daunting undertaking and previous CFD models have simplified the anatomy. Micro-computed tomography data were collected on an African grey parrot infused with BrightVu® contrast agent. A three-dimensional surface model was then generated by segmenting regions of interest in the left lung. This has allowed for extremely precise anatomical measurements to be made, laying the foundation for future development of a CFD model. The cross-sectional areas of the ostial openings off the primary bronchus and branching angles of all secondary bronchi, including four ventrobronchi, nine dorsobronchi, and three latero-bronchi were measured digitally. Moving cranial to caudal in the primary bronchus, the ostia increase in diameter in successive ventrobronchi, and decrease in diameter in the dorsobronchi.

P3-272 MASS, SM; FUNK, A; WILLS, N*; PINSKY, B; MASSENA, K; CHABRIA, T; MINICOZZI, M; MIYNARSKA, I; MOODY, T; ST. JOHN, P; SUNY New Paltz, Northern Arizona University; *willsn1@hawkmail.newpaltz.edu*
The cytokeleton, endocrine disruption and regeneration
Environmental xenoestrogens such as Bisphenol-A (BPA), have been shown to depress and delay regeneration in a variety of flatworms at high doses, and to work in a non-monotonic fashion and stimulate regeneration at very low doses. Prior work in our lab has suggested that bisphenol compounds are interacting with an ER-like pathway in planaria. In vertebrate systems, weak estrogen receptor (ER) agonists like BPA are known to repress ER responses at high doses and increase ER responses at low doses in a manner very similar to the decrease and increase in growth we observe in regenerating planaria. Since regeneration involves both proliferation and cell movement, we hypothesized that cytoskeleton may be one of the mechanisms by which endocrine disruptors are affecting regeneration in flatworms. In this work we compare the effects both tubulin stabilizing and disrupting agents and examine the actin and tubulin cytoskeleton in regenerating planaria exposed to BPA.

P3-276 MASSENA, K*; FUNK, A; WILLS, N; CHABRIA, T; PINSKY, B; DANISEWICZ, E; THOM, Z; MASS, S; SUNY New Paltz; *massenak1@hawkmail.newpaltz.edu*
Preservatives that synergize with xenoestrogens: effects of co-administration of BHT and BPA on regeneration in Planaria
Butylated hydroxytoluene (BHT) is a commonly used food additive and antioxidant. Bisphenol-A (BPA) is a known xenoestrogen which is used to synthesize polycarbonate plastics, epoxy resins and numerous plastic materials used in packaging. Interestingly, BHT and BPA are found together in cases where plastic packaging is used for food, cosmetic and household products. While BHT is an FDA approved additive for food, health and beauty products, it has known toxicity, especially in aquatics, and has long been suspected as a possible carcinogen. Prior work in our lab has shown that BPA can have deleterious effects on planarian regeneration. In this study we demonstrate that BPA synergizes the lethal effects of BHT at high doses in planaria (LC_{50} BHT ~64 μM; whereas ~15 μM in presence of sublethal dose of BPA) and examine the effects of coadministration of BHT with BPA on regeneration in planaria.

97-1 MATLOFF, LY*; CHANG, E; STOWERS, AK; FEO, TJ; THOMSON, C; LENTINK, D; Stanford University , Smithsonian Institution, Division of Birds; *lmatloff@stanford.edu*

Multi-element wings: How coordinated feather motion enables avian wing morphing

Feathers allow birds to morph their wings through continuous shapes, enabling them to control their aerodynamic wing planforms to attain maximal flight performance and maneuver. Each unique feather moves in concert with its neighbors in an under-actuated system controlled by skeletal motion. By studying feather motion and friction forces, we gain further insight into the underlying mechanisms of feather-to-feather interactions. Kinematic measurements of pigeon wings, *Columba livia*, were obtained using a motion capture camera system, and feather friction was measured with a six-axis force and torque transducer. We then corroborated models to describe feather motion to explain how feathers shape the wing during morphing. Using the data and model, we subsequently develop a robotic mechanical model, which we test in outdoor free flight. Together, the measurements, theory, and mechanical models advance our understanding of how birds control their feathers via the skeleton, and how tendons and feather friction enable feather underactuation.

83-1 MATSUDA, SB*; GATES, RD; Hawaii Inst. of Mar. Biol.; *shayle@hawaii.edu*

Too hot to handle: How algal and bacterial microbial communities influence the thermal tolerance of corals

Scleractinian reef corals exist in an obligate symbiosis with single-cell dinoflagellates (*Symbiodinium* spp.). Reef corals live 1 - 2°C from their upper thermal limit, and episodic or seasonal ocean warming facilitates the breakdown of the coral-*Symbiodinium* partnership (i.e., coral bleaching) that can cause coral mortality. The performance of reef corals during (and following) temperature stress depends on characteristics of the coral holobiont (host + symbiont + microbes). *Symbiodinium* assemblages and bacterial communities are integral to coral host nutrition, defense, and physiology, and have been shown to influence coral stress responses. Here, we examine how both *Symbiodinium* and bacterial communities contribute to the thermal tolerance of four coral species in Kāneʻohe Bay, Hawaiʻi (*Montipora capitata*, *Porites compressa*, *Pocillopora acuta*, and *Pavona varians*) that differ in key functional traits: skeletal morphology, tissue thickness, and *Symbiodinium* transmission mode and assemblages. Twelve genotypes per species (n=5 genotype^{-1}) were placed into ambient (ca. 28°C) or high (ca. 31°C) temperature treatments for 2 weeks, and then held at 28°C for one month for a period of physiological recovery. DNA was assayed at three time points: prior to heat stress, after high temperature exposure, and after one month of recovery. Treatment effects on microbial community assemblages were identified through amplicon sequencing of 16S and ITS2. Together, our across species comparison of coral physiological performance with microbial communities offers clarity on their role in holobiont thermal tolerance. As global climate change and ocean warming continue to threaten coral reefs, this knowledge can be leveraged to improve conservation and management of coral reefs.

48-4 MATSUMOTO, Y*; MIGLIETTA, MP; Texas A&M University, Galveston; *yuim@tamu.edu*

Reverse development in Turritopsis dohrnii: Model system for regeneration, cellular plasticity and aging

Turritopsis dohrnii (Cnidaria, Hydrozoa) undergoes lifecycle reversal to avoid death caused by physical damage, adverse environmental conditions, or aging. This unique ability has granted the species the name, the "Immortal Jellyfish". *T. dohrnii* exhibits an additional developmental stage to the typical hydrozoan lifecycle which provides a new paradigm to further understand regeneration, cellular plasticity, and aging. Weakened jellyfish will undergo a whole-body transformation into a cluster of uncharacterized tissue, referred to as the cyst stage, which then will metamorphoses back into an earlier lifecycle stage, the polyp. The underlying cellular processes that permit its reverse development is called transdifferentiation, a mechanism in which a fully mature and differentiated cell can switch into a new cell type. The polyp, jellyfish and cyst stage of *T. dohrnii* were sequenced through RNA-sequencing, and the transcriptomes were assembled de novo, and then annotated to create the gene expression profile of each stage. Comparative functional gene enrichment analyses with the cyst as the central stage of comparison reported significant GO categories that were over-expressed, such as telomere maintenance and DNA repair, in the cyst as compared to other stages. The enrichment analyses also reported significantly under-expressed categories, such as mitotic cell division, cellular differentiation and development, in the cyst as compared to the other stages. Ultimately, our work produced a foundation to develop an alternative model system to further investigate and comprehend regeneration, cellular plasticity and aging in metazoans.

30-5 MATTHEWS, DG*; ALBERTSON, RC; Harvard University, University of Massachusetts Amherst; *davematthews@g.harvard.edu*

Effect of Craniofacial Genotype on the Relationship between Morphology and Feeding Performance in Cichlid Fishes

The relationship between morphology and performance is complex, but important for understanding the adaptive nature of morphological variation. Recent studies have sought to better understand this system by illuminating the interconnectedness of different functional systems, however the role of genetics is often overlooked. In this study we attempt to gain insights into this relationship by examining the effect of genotypic variation at putative craniofacial loci on the relationship between morphology and feeding performance in cichlids. We studied two morphologically disparate species, as well as a morphologically intermediate hybrid population. We assessed feeding performance, jaw protrusion, and general facial morphology for each fish. We also genotyped hybrid animals at six previously identified craniofacial loci. Cichlid species were found to differ in facial geometry, kinematic morphology, and performance. Significant correlations were also noted between these variables, however the explanatory power of facial geometry in predicting performance was relatively poor. Notably, when hybrids were grouped by genotype, the relationship between shape and performance improved. This relationship was especially robust in animals with the specialist allele at *sox9b*, a well characterized regulator of craniofacial development. These data suggest a novel role for genotype in influencing complex relationships between form and function.

125-1 MATZ, MV*; HALLER, BC; TREML, EA; Univ. of Texas at Austin, Cornell University, Univ. of Melbourne; *matz@utexas.edu*
Predicting coral adaptation and extinction in the Coral Triangle.
Can corals adapt to the current rate of sea surface warming? One possibility for such rapid adaptation is by "genetic rescue", involving the spread of pre-existing heat-tolerance alleles from warmer to cooler locations. We have developed an individual-based model of this process and used it to generate a map of times to extinction for the whole Coral Triangle. We used a migration matrix between >600 reefs derived from the biophysical model of larval dispersal and assumed relative population sizes proportional to the reef area. Varying the poorly known parameters of the adaptation model, such as heritability and plasticity of heat tolerance, number and effect size of adaptive loci, and absolute population size, had little effect on the ranking of reefs according to time to extinction (Spearman rho >0.89 between alternative parameter settings). Present-day temperature is the strongest predictor of time to extinction, explaining 51% of variation (warmer locations go extinct sooner), followed by reef area (21% of variation explained, smaller reefs go extinct sooner) and immigration rate (6% of variation explained, higher immigration delays extinction). Reefs that are predicted to survive the longest are well-connected high-latitude reefs such as middle and southern Great Barrier Reef and Lord Howe Island. The most rapid extinction is predicted for isolated reefs in already warm locations, such as Thailand, Cambodia, and Gulf of Carpentaria. Notably, reefs in Western Australia are also predicted to go extinct relatively soon despite their high-latitude location, due to the lack of immigration from warm-adapted populations. We show that coral extinction at these reefs can be substantially delayed through feasible assisted migration efforts.

60-2 MAURO, AA*; HAVIRD, JC; GHALAMBOR, CK; Colorado State University; *Alexander.Mauro@colostate.edu*
Plasticity's Role in Adaptation to a Novel Environment
While plasticity as long been recognized as an ubiquitous feature of organisms, plasticity's role in influencing adaptive adaptation is increasingly being debated. Investigating how plasticity influences evolution has been challenging in natural populations because of the difficulty of capturing the dynamics during the early stages when populations are diverging. We overcome these challenges by studying the plasticity of gene expression in wild populations of Trinidad guppies (*Poecilia reticulata*) that have been experimentally introduced to predator free streams, which is a novel predatory state. We used RNASeq to measure the evolution of gene expression in the introduced populations, source population, and an already established low predation (target) population reared under common garden conditions. To test changes in plasticity fish were reared under ancestral conditions of predation and the novel condition of no predation. Gene expression was measured annually over the course of 3 years (10+ generations). Initial rapid evolutionary change in expression counter to the direction of ancestral plasticity and toward the target population was observed in the intro populations after 3-4 generations, supporting the theory of genetic compensation. Plasticity itself also decreased in the intro populations over this time. However, over longer time periods evolutionary divergence appears to slow, as plasticity decreased, suggesting that plasticity plays a vital role in rapid adaption to novel environments by altering the strength of selection acting on the population.

140-1 MAY, MA*; RAWSON, PD; California Polytechnic State University, University of Maine; *mmay09@calpoly.edu*
Ornithine Metabolism and the Osmotic Stress Response in Mytilids
Previous studies of transcriptomic responses to hypoosmotic exposure in blue mussels (*Mytilus* spp.) have suggested differential utilization of the amino acid ornithine among congeneric species. Ornithine catabolism is used to generate glutamate or proline through the activity of ornithine aminotransferase (OAT), or to create putrescine and other polyamines through activity of ornithine decarboxylase (ODC). Variation in expression of genes involved in ornithine metabolic pathways may help to explain differences in the salinity tolerances of *M. galloprovincialis*, *M. trossulus*, and *M. edulis*. This study was undertaken to better understand the potential role of OAT and ODC in blue mussels during exposure to altered salinity, as well as to examine the variation in gene expression across developmental stages and between species. We found that OAT gene expression increases during low salinity exposure in all three species, and that in *M. edulis* increased expression was associated with increased OAT enzyme activity. We observed that ODC tended to be downregulated during hypoosmotic exposure, although the response was typically smaller that that of OAT and inconsistent among individual mussels. During hyperosmotic stress, the patterns of expression of these two genes reversed, suggesting that synthesis of proline or glutamate is important during low salinity exposure but that polyamine synthesis may be more important during hyperosmotic exposure.

P1-196 MAY, C*; HILLERBRAND, N; THOMPSON, L; FASKE, T; PARRY, D; MARTINEZ, E; AGOSTA, S; GRAYSON, K; Univ. of Richmond, VA, Virginia Commonwealth Univ., Richmond, State Univ. of NY School of Environmental Science and Forestry, Syracuse, Bosque Estatal de Guánica, San Juan, PR; *carolyn.may@richmond.edu*
Metabolic Acclimation to Temperature in Invasive Populations of Gypsy Moth (Lymantria dispar) from Latitudinal Extremes
Acclimatization is an important mechanism for ectotherms to maintain homeostasis as environments become thermally stressful. Thermal regimes can be highly variable across the range of a species, and accordingly, populations can differ in their response to changing environmental conditions. The North American spread of the gypsy moth is an exemplar system for studying population variation in physiology after a rapid range expansion, as gypsy moth now occupies a wide gradient of climates across its invasive range. This study quantified differences in metabolic thermal sensitivity across temperature for two northern and two southern gypsy moth populations using stop-flow respirometry after acclimating larvae to high or low rearing temperatures. We measured the effect of rearing temperature on acclimation response of metabolic rate in each population, as well as the metabolic response of populations from the north and south range extremes when reared at the same temperature. Overall, there was a significant increase in metabolic rate with increasing respirometry temperature. These data do not provide evidence for metabolic adaptation to temperature based on population, as acclimation to rearing temperature was more predictive of metabolic rate than geographic origin of the population. Understanding the response of gypsy moth to temperature, particularly in populations at range extremes, is important for understanding future range dynamics in this species and in other invasive systems.

P1-8 MAY, MA*; VASQUEZ, MC; TODGHAM, AE; TOMANEK, L; California Polytechnic State University, University of California, Davis; *mmay09@calpoly.edu*

It Takes a Village: Lessons from Conducting Large-scale Physiology Experiments

Our lab is interested in understanding how organisms respond to environmental stressors by evaluating the stress response at multiple levels of biological organization with high temporal resolution. However, conducting experiments that assess changes at the molecular to whole organismal level at multiple time points requires extensive planning and a concerted effort from a group of well-trained scientists. We found in a recent study that undergraduates, with guidance and training, can provide invaluable assistance in large-scale experiments. Our students aided in data collection and, more importantly, helped to develop protocols, design equipment, coordinate other students to successfully execute measurements of multiple phenotypes throughout an intensive, week-long sampling regime, and analyze data. This provides the undergraduates with an unmatched learning experience: students get first-hand knowledge of what it takes to conduct large experiments; they have ownership over the aspects of the experiments they helped develop; and they receive training along every step of the process. This synergy benefits all members of the team and helps improve the quality of science being conducted. From our experience, we have created a working model of large-scale undergraduate research, which offers unique opportunities for building successful research teams and enables multi-scale experimental designs that can help resolve complex biological problems (funded by NSF IOS-1557500).

134-3 MAYERL, CJ*; BLOB, RW; Clemson University; *cmayerl@clemson.edu*

How flowing water influences hydrodynamic stability in turtles

The costs of steady swimming can represent most of the daily energy budget of aquatic animals. Maintaining stability while swimming is thought to provide energetic advantages that can limit such costs, as well as sensory advantages. However, environmental fluctuations can dramatically influence animal behavior and performance. In water, one of the most common types of environmental fluctuation is changes in water flow conditions. How well can stability be maintained under changing flow conditions? We measured the stability of two different species of turtle, the pink bellied side-necked turtle (*Emydura subglobosa*) and the painted turtle (*Chrysemys picta*) as they swam in still water, as well as water flowing at 1 and 2 body lengths/sec. We found that both species increased their velocity at faster flow speeds. They achieved these higher speeds by increasing stride length rather than stride frequency, but the two species did so in different ways. *E. subglobosa* increased stride length through greater retraction of its arms and protraction of its legs, whereas *C. picta* increased stride length through greater protraction of its arms and greater retraction of its legs. *E. subglobosa* was more stable in still water than *C. picta* but, as flow speeds increased, *C. picta* became more stable than *E. subglobosa*. Our results show that animals may respond to changing conditions in an overall similar manner by increasing stride length, but that the mechanism behind increased stride length may differ, and these differences may result in differences in performance in across varying environments.

P2-269 MAYNARD, R.H.*; WARNERT, R.; LENT, D.D.; Cal State Univ Fresno; *reomaynard@mail.fresnostate.edu*

Visual navigation in the carpenter ant, Camponotus essigi.

Among the central-place foraging ants, some wood ants are known to rely on robust visual cues to facilitate navigation. However, the mechanism some carpenter ants, which forage in the same areas as do wood ants, use these visual cues successfully to navigate isn't well understood. To explore the visual features the carpenter ant (Camponotus essigi) uses for navigation, we trained a queen right colony over several weeks. Our experiment involved rewarding ants with sucrose upon reaching the base of a black cylinder landmark. Integrated into the training were two types of unrewarded tests. The first examined the ants' ability to use the center of mass of an object (a black cylinder) as a useful feature from which to build a working memory for route navigation, and then to see if that memory might be carried over to a visually distinct object (a black cone). The second test looked at whether ants would continue to rely on the center of mass for navigation or possibly switch to other defining characteristics such as edges. This was determined based on how frequently the ants traveled toward the distinct, cone shape when given the choice between the two. Preliminary data shows that carpenter ants, using sucrose as a reward, can be readily trained to seek out specific landmarks. When tested on the novel landmark (black cone), ants likewise sought it out and conducted search patterns at its base for the sucrose reward. When presented with both the trained and the novel landmark, ants showed a distinct preference for the trained landmark. Our data suggests that, like the wood ant (Formica rufa), carpenter ants can discriminate between multiple characteristics of landmarks and use those for route navigation.

P2-238 MÜLLER, UK*; LI, G; BERG, O; VAN LEEUWEN, JL; CSU Fresno, Chiba University, Wageningen University; *umuller@csufresno.edu*

Bladderwort Suction Feeding - Insights from Mathematical Models

Bladderworts, a genus of carnivorous plants, are among the smallest and fastest suction feeders. Their traps, typically 1 to 5 mm in diameter, catch zooplankton that ranges in size up to the diameter of the trap opening (100 to 300 microns). At such a small gape, bladderworts could be expected to feed in the viscous flow regime. However, experiments have shown that the traps generate extremely fast-onset, strong suction pressures, which in turn generate fast enough flows to allow bladderworts to escape the viscous flow regime. We used mathematical models (computational fluid dynamics and analytical models) to explore the effects of gape diameter, pressure, and time to peak pressure on the flow generated by bladderwort traps. We found that the flow generated by bladderwort suction events is inertia-dominated. In contrast to first-feeding larval fish, which have a similar gape diameter to bladderwort traps, we found that bladderworts are not near the lower size limit. Previous theoretical and experimental studies on larval fish found that larval fish suction-feed near the lower size limit, where small changes in size have a large effect on flow and capture success. In bladderworts, similar changes in gape size do not significantly affect flow, and the traps continue to feed in the inertia-dominated flow regime. Our computational models further predict that time to peak pressure (instantaneous onset versus gradual onset) has no strong effect on suction flow characteristics that correlate with prey capture success, such as peak flow speed and peak spatial pressure gradient; we found no evidence of unsteady effects enhancing flow speed or spatial pressure gradient. We conclude that bladderworts feed in the inertial flow regime mainly due to the high pressures that they generate rather than due to the fast onset of pressure.

P3-121 MCALPINE-BELLIS, EA*; GARRISON, GE; GILBERT SMITH, S; KLEIN, JRV; UTSUMI, KL; DIAMOND, KM; EIFLER, D; EIFLER, M; University of California, Berkeley, University of California, Davis, University of Kansas, Clemson University, Erell Institute; *mcalpine.liz@berkeley.edu*

Where to Find the Best Bugs: A Study of Habitat Use Among Lizard Species with Different Movement Strategies

Sensory systems used to find prey can affect multiple aspects of predator ecology. To examine the influence of prey detection on the movement of organisms through their environments, we observed two sympatric species of lizards that find prey via different sensory cues. The Alvord Basin in southeast Oregon is a high elevation desert inhabited by two species of similar-sized lizard with a similar prey base, the long-nosed leopard lizard, *Gambelia wislizenii*, which is primarily a visual hunter, and the western whiptail, *Aspidoscelis tigris* , which relies heavily on chemosensory cues to find prey. Our goal was to determine if there were consistent differences in habitat use and movement patterns of each species that coincided with their different prey sensing abilities. We predicted that visual predators would move less and make more use of open spaces, whereas predators relying on chemosensory cues would make more frequent movements and make more frequent use of the available vegetation. The more visually-oriented leopard lizards spent more time in open areas, moved less frequently over shorter distances, and had lower variation in the types of plants used to perch compared to the chemo-oriented whiptails. Our results are consistent with predictions that follow from the hunting strategy of each species; differences in prey sensing systems and related movement patterns can promote cohabitation in a resource limited environment.

P3-234 MCBRAYER, LD*; ORTON, RW; KINSEY, CT; Georgia Southern University; *lancemcbrayer@georgiasouthern.edu*

Habitat management affects traits tied to individual fitness: parasites, signals, and performance

Organismal fitness is determined by a myriad of underlying morphological, physiological and genetic traits. In turn, selection may act differentially on these traits due to ecological factors such as population density, habitat quality, parasitism, or predation. The result is a mosaic of organism-environment correlations that ultimately govern individual reproductive success, and the adaptive landscape across populations. Today, anthropogenic habitat management is increasingly necessary, and problematic. By definition, management alters the habitat, often with a particular goal in mind (e.g. understory removal), and thus may alter the ecology of the constituent species. Understanding these effects has yet to receive considerable attention for many small, non-game, non-threatened species. In North America, both long leaf pine and Florida scrub habitats maintain 3% or less of their historic range, and are intensely managed. Our work suggests that Florida Scrub Lizards *(Sceloporus woodi)* suffer greater predation risk and lower population densities in clear cut stands of Florida scrub compared to burned long-leaf stands. Long-leaf and scrub populations are also shown to differ in ectoparasite load. In this study, we will investigate if male color badge brightness is correlated to stand type and/or ectoparasite load. We also quantify and compare sprint performance and endurance to establish a mechanistic understanding of predation, parasitism, and differential fitness in managed landscapes.

140-3 MCCAIN, SC*; EARLEY, RL; University of Alabama, Tuscaloosa; *scmccain@crimson.ua.edu*

Age-dependent responses to an extreme salinity gradient in a euryhaline fish

Selection should favor individuals that choose to occupy habitats that confer highest fitness. In heterogeneous environments, this often equates to individuals actively navigating alternative habitat types and dispersing to areas that offer higher potential for survival and reproduction. When habitat preferences exhibited in the lab do not align with the conditions under which individuals are found in natural environs, it suggests that: i) some other element precludes optimal habitat choice in the wild, and ii) the potential for measurable fitness consequences experienced by individuals occupying subpar habitats. Mangrove rivulus fish inhabit salinities ranging from 0 to 65 ppt but are most often collected at ~25 ppt. However, recent experiments showed that rivulus prefer to occupy lower salinities (5-15 ppt). To evaluate the fitness consequences of living in various salinities across ontogeny, fish from three life stages (hatchling, juvenile, adult) were randomly assigned to one of 7 salinities between 5 - 65 ppt for two weeks. Growth rate and mortality were quantified as fitness proxies. Hatchling survival decreased by ~10% between 5 and 25 ppt but, mortality increased precipitously as habitats became more saline. Hatchlings also showed significantly greater mass gain at 5 and 15 than at 25 ppt, and considerably less as salinity increased further. Juveniles did not experience significant mortality until 55 ppt and gained more mass at 5, 15 and 25 ppt than at higher salinities. Adults appeared unaffected by salinity, with no difference among salinities in mass gained and a slight increase in mortality at 65 ppt. For species inhabiting variable environments with multiple microhabitats, fitness might be maximized in habitats that are quite different from those in which the animals are commonly found in the wild.

23-2 MCCORMLEY, M*; CHAMPAGNE, C; DEYARMIN, J; STEPHAN, A; HOUSER, D; CROCKER, D; KHUDYAKOV, J; University of the Pacific , Old Dominion University, University of the Pacifc, University of the Pacific, National Marine Mammal Foundation, Sonoma State University; *mmccorml88@gmail.com*

Using endocrine profiles to discriminate stress states in marine mammals

Understanding how marine mammals respond physiologically to anthropogenic stressors can inform marine ecosystem conservation strategies. Stress stimulates release of glucocorticoid (GC) hormones, which increase energy substrate availability while suppressing energy-intensive processes. Exposure to repeated stressors potentially affect an animal's ability to respond to and recover from subsequent challenges. To assess the endocrine response of the elephant seal (Mirounga angustirostris) to repeated stressors, we administered adrenocorticotropic hormone (ACTH) to juvenile seals (n=7) once daily for four days. ACTH administrations induced significant, transient (lasting <24 h) elevations in circulating cortisol ($p < 0.0001$). These increases did not vary in magnitude between day 1 and day 4. In contrast, aldosterone levels remained elevated above baseline for at least 24 hours after each ACTH injection ($p < 0.001$), with responses being greater on day 4 ($p < 0.01$). Total triiodothyronine (T3) levels were decreased on day 4 ($p < 0.01$), while reverse triiodothyronine (rT3) concentrations increased relative to baseline on days 1 and 4 ($p < 0.001$), indicating potential metabolic suppression. These data suggest that repeated stress results in facilitation of aldosterone secretion and suppression of total T3, which may have long-term physiological impacts. However, this did not seem to impair the seals' ability to mount an adrenal response to each ACTH challenge. We propose that aldosterone may be a more informative indicator of repeated stress exposure than cortisol in some marine mammals.

121-2 MCCUE, MD*; BARTON, M; TERBLANCHE, JS; St. Mary's University, Stellenbosch University; *mmccue1@stmarytx.edu*
Improving Respirometry Equations for Robust Estimates of Metabolic Rate Across Diverse and Extreme Experimental Gas Conditions
One inadvertent consequence of many commonly-employed respirometry equations is that they produce biologically unrealistic estimates of animal metabolism in situations where the composition of respiratory gases (i.e., O_2 and CO_2) differs strongly from the atmosphere (i.e., hyperoxia, hypoxia, or hypercapnia). This suggests that an alternative set of respirometry equations might prove useful under these specific experimental conditions. We measured changes in fractional concentrations of respiratory gases in laboratory mice and other animals across a range of ambient O_2 and CO_2 concentrations to illustrate the nature and magnitude of these potential errors. We show that the fractional changes in animal O_2 and CO_2 caused by metabolism are relatively independent of the ambient $O_2$and CO_2 concentrations in acute experiments - in agreement with conventional wisdom - but in clear contrast to the results that would be obtained from many respirometry equations. The magnitude of these errors increases exponentially as experimental conditions increasingly deviate from atmospheric conditions. In fact, some of the most frequently used equations were found to overestimate metabolic rates by several-fold. We conclude that respirometry equations comprising both a numerator and denominator term, which may work perfectly well for normoxia gas conditions, are particularly error-prone, and that the denominator terms [e.g. $(1-F_{inspired}O_2)$ or $(1-F_{expired}O_2)$] drive the error in the metabolic estimates. We also demonstrate these errors in an R software computer simulation. We attribute these errors to the propagation of assumptions in a paper published over 60 years ago, and expect that countless reports of metabolic rates have may have propagated these them. We conclude by proposing a simple set of respirometry equations that researchers can use to calculate metabolic rate independent of ambient gas concentrations, thus overcoming this particular limitation of the main equations advocated for use in respirometry.

P1-116 MCCULLOCH, K/J*; KOENIG, K/M; Harvard University; *kyle_mcculloch@fas.harvard.edu*
Neural and optic expression of Sp/KLF transcription factor family in the longfin shore squid, Doryteuthis pealeii
The evolution of transcription factor (TF) families and their functions during animal evolution is poorly understood. Comparative assessments for even the best-understood TFs are limited by a lack of information from major animal groups outside the vertebrates and arthropods. To broaden our understanding of TF evolution outside of these animal groups we use the eye of the squid, *Doryteuthis pealeii*, which has convergently evolved a similar structure to the vertebrate eye, as a comparative model for development of a complex trait. Krüppel-like and specificity protein (KLF/Sp) transcription factors are zinc finger proteins characterized by a DNA binding domain of two cysteines and two histidines (C2H2) repeated in triplicate. In vertebrates and fruit flies, KLF/Sp genes are known to be involved in diverse metabolic, and developmental processes, including in head formation in *Drosophila* and lens and cornea development in mice. Outside of these groups, Sp6-9 is necessary for optic cup regeneration in planarians, but little else is known about KLF/Sp expression patterns or function. Using RNA sequencing of developing eye and optic lobe tissue we found that several of these genes are expressed in *D. pealeii*. We identified and phylogenetically placed *D. pealeii* KLF/Sp family members and characterized the DNA-binding transactivation and repression domains from the predicted amino acid sequences. We then characterized the spatial expression patterns of these genes using *in situ* hybridization to better understand their potential role in *D. pealeii* visual system development. We found multiple KLF/Sp genes in *D. pealeii* expressed specifically in neural, optic lobe, retinal, and anterior segment patterns. These results are the first evidence of the KLF/Sp gene family's role in eye development in molluscs and may contribute to cephalopod-specific novelties such as the lens.

55-4 MCELROY, EM*; HEURING, C; WILLIAMS, D; College of Charleston, Texas Christian University; *mcelroye@cofc.edu*
Colonization success in a specialist: morphology, diet and genetics of introduced populations of the ant-eating Texas horned lizard, Phrynosoma cornutum.
Introduced species can diverge from their source population when established in a new ecosystem. The Texas horned lizard (*Phrynosoma cornutum*) is native to the western United States, but was historically introduced to several locations in the southeastern United States. We studied three introduced populations in South Carolina to determine 1) if the introduced populations exhibit dietary, morphological and genetic divergence from the native western populations and 2) if diet, morphology and genetics significantly vary between the three introduced populations. We expected little divergence from western populations and among introduced populations because *P. cornutum* is a highly specialized species whose biology is shaped by its diet of *Pogonomyrmex* harvester ants. Our data show that the introduced populations experienced founder effects and went through a bottleneck that resulted in decreased genetic diversity. However, introduced populations are still genetically distinct from each other and exhibit genetic diversity similar to some western populations found in urban areas. South Texas was likely the source population for the introduction. The majority of the diet in South Carolina is ants (94%), but surprisingly, *P. cornutum* in South Carolina do not eat *Pogonomyrmex* harvester ants. Introduced lizards primarily eat *Dorymyrmex* ants, but each introduced population complement *Dorymyrmex* with significantly different amounts of other species of ants, insects and plant matter. Introduced populations differ in limb and head shape when compared to western populations and when compared to each other. This study shows a dietary specialist can exhibit phenotypic change that allows it to take advantage of ecological opportunity in the introduced range.

126-7 MCENTIRE, K D*; MAERZ, J C; HOWARD, J S; University of Georgia; *mcentire@uga.edu*
Integrating Modeling and Fieldwork to Explore How Behavior Moderates Salamander Sensitivity to Climate
Models are a useful tool to understand the mechanisms driving organisms' interactions with climate. Biophysical models can predict how an organism will interact with environmental variability. The deterministic nature of such models can make them unrealistic, especially in the context of behavior which can alter physiological interactions. Agent based modeling offers a unique structure to incorporate biophysical models and test potential compensatory behaviors for how organisms deal with microclimate. We used salamanders in Southern Appalachia as a model system because the region is characterized by steep microclimatic gradients and abundant salamanders. Well established biophysical models for plethodontid salamanders provide a unique opportunity to mechanistically model the interactions of compensatory behaviors with microclimatic differences. We used plant climbing as a compensatory behavior for salamanders to interact with microclimate differences. We also established plots along a precipitation gradient in Western North Carolina to field validate the model's predictions. The simulation models predict increased climbing behavior in the fall to increase activity time and compensate for temperature differences. The field data supports this result with higher proportions of climbing animals in the fall and suggests a strong relationship between climbing and soil temperature. This support of the mechanistic model emphasizes the importance of including behavior in predictive models.

P1-98 MCFARLAND, S*; SUQUILANDA, D; VELEZ, K; DIVINO, J; SCHULTZ, E; MONETTE, MY; Western CT State Univ., Univ. of CT, Storrs; *mcfarland013@connect.wcsu.edu*

The Role of the Na-Cl Cotransporter in Freshwater Adaptation of Threespine Stickleback

The Threespine Stickleback (*Gasterosteus aculeatus*) provides an excellent euryhaline fish model for examining the evolution of physiological traits such as ion regulation. Ancestral, oceanic populations of stickleback have become isolated and often landlocked in novel freshwater environments across the Northern Hemisphere, and recent investigations have shown landlocked stickleback exhibit a trend of increased freshwater tolerance when compared to ancestral, oceanic fish, despite both populations being euryhaline. It is likely that differences in ionoregulatory performance are due to differences in expression and regulation of ion transport genes, however it is also possible that divergence in protein sequence has led to changes in structure and function that are favorable for freshwater adaptation. We examined the protein sequence of the Na-Cl cotransporter (NCC) in individuals from oceanic (Rabbit Slough and Resurrection Bay) and freshwater-landlocked populations (Frog Lake and Bear Paw Lake). We determined that NCC of oceanic and freshwater-landlocked stickleback differed consistently at four amino acid positions. Three of these positions (413, 415, 430) were found in the large extracellular loop between transmembrane 7 and 8; a fourth position (682) was located in the large intracellular C-terminus. While the C-terminus' specific function remains unknown, the large extracellular loop region of NCC is involved in ion transport and trafficking. Future research will examine NCC protein sequence in additional oceanic and freshwater-landlocked populations as well as examine whether identified amino acid differences have led to functional changes in NCC advantageous for physiological adaptation to novel freshwater environments.

50-5 MCGIRR, JA*; MARTIN, CH; Univ. of North Carolina, Chapel Hill; *joemcg318@gmail.com*

"Different different but same": Parallel gene expression between trophic specialists despite divergent genotypes and morphologies

There are many cases of parallel gene expression underlying the evolution of convergent niche specialization, but parallel expression could also underlie divergent specialization. We combined transcriptome sequencing with genome-wide divergence scans to study the molecular evolution of two specialist Cyprinodon pupfish species - a 'scale-eater' and a 'snail-eater' - that rapidly diverged from a sympatric generalist ancestor within the last 10,000 years. These specialist species are adapted to highly divergent niches that are unique within atherinomorphs. We identified 16 million single nucleotide polymorphisms, 11 million indels, and 7,394 differentially expressed genes by whole-genome resequencing of 42 individuals and transcriptome sequencing of 29 individuals. 82% of genes that were differentially expressed between snail-eaters and generalists were up or downregulated in the same direction between scale-eaters and generalists, indicating significant parallel gene expression between divergent specialists. Surprisingly, there were no shared fixed variants underlying this parallel expression. Genes showing parallel expression were enriched for effects on metabolic processes, whereas genes showing divergent expression were enriched for effects on cranial skeleton development and pigment biosynthesis, reflecting the most divergent phenotypes observed between specialist species. Together, our findings show that convergent adaptation to higher trophic levels in divergent specialists is driven by unique genetic variants regulating the same gene networks.

P1-26 MCGROSKY, A*; KAMILAR, JM; TECOT, SR; SCHWARTZ, GT; Arizona State Univeristy, Univ. of Massachusetts, Amherst, University of Arizona, Arizona State University; *amcgrosk@asu.edu*

Comparative aspects of mammalian pituitary gland anatomy and its usefulness for reconstructing life history

Pituitary hormones related to growth and reproduction play a central role in regulating mammalian life history. Recent work has shown that pituitary gland size can predict growth rates in extant mammalian species, with larger anterior pituitary lobes linked to faster fetal and postnatal growth. Given the link between pituitary gland volume and growth rates, estimating pituitary size in extinct species would provide a novel way to infer one aspect of growth in the past. The pituitary gland is seated within the sella turcica of the sphenoid bone and the bones of the sella turcica form around the developing pituitary gland. Therefore, we predict that the volume of the sella turcica will track pituitary gland volume such that mammalian species with larger glands will have greater bony dimensions. Additionally, we predict that growth rates increase as sella turcica volume increases. We gathered anterior and posterior pituitary lobe, as well as total gland, volumes for mammalian species from the literature. Data on sella turcica dimensions for representatives of the same species were measured from microCT reconstructions of crania available from online CT databases. Using PGLS, we show that the volume of the sella turcica increases as pituitary gland volume increases ($p<0.05$) and that one key measure of growth, postnatal growth rate, increases as sella turcica volume increases ($p<0.05$). This represents a novel approach to reconstructing growth rates in the past and adds a new dimension to explorations of mammalian life history evolution.

P2-88 MCGUIRE, LP*; FULLER, NW; HAASE, CG; SILAS, KA; OLSON, SH; Texas Tech Univ., Lubbock, Montana State Univ., Bozeman, Wildlife Conservation Society, Bronx; *liam.mcguire@ttu.edu*

Regional Variation in Hibernation Phenotype: Myotis velifer Hibernation at Southern Latitudes and Implications for White-Nose Syndrome

Hibernation research often focusses on extreme hibernation phenotypes associated with long periods of hibernation. At high latitudes, bats may approach their physiological limits as they deposit large fat stores and use long torpor bouts to survive long winters. However, more southern populations may not hibernate in the same way. As part of a larger project examining the implications of white-nose syndrome for bats in Western North America, we examined the behavior and physiology of hibernating *Myotis velifer* in Western Oklahoma where winter is comparatively short. We used quantitative magnetic resonance to measure body composition, respirometry to determine torpid metabolic rate, radiotelemetry to record torpor arousal dynamics, acoustic monitoring for activity outside the hibernaculum, and recorded temperature and humidity throughout the hibernaculum. Despite the relatively short winter, *M. velifer* deposited large fat stores comparable to those at northern latitudes, and did so in a sex-biased manner. Bats remained relatively active throughout much of the winter, except during notable weather events, and roosted in areas that did not correspond to minimum metabolic rate. This study suggests *M. velifer* fall on the other end of the hibernation phenotype spectrum. Winter is comparatively mild, but bats deposit large energy stores that enable them to hibernate in a manner that does not minimize energy expenditure. With these field data, we are currently developing bioenergetic models to predict the impact of white-nose syndrome in this species and others across the West.

P2-216 MCINROE, B*; GOLDMAN, DI; FULL, RJ; University of California, Berkeley, Georgia Institute of Technology; *bmcinroe@berkeley.edu*

Substrate Volume Fraction Predicts Burrowing Dynamics in Sand Crabs

Terrestrial animals locomote over, manipulate, and make ingress into a variety of natural substrates. Movement in flowable substrates like sand and mud that exhibit both solid and fluid-like behavior is particularly complex. Burrowing into such substrates requires the animal to overcome potentially large material stresses and contend with time-varying substrate properties. To develop principles for effective burrowing, we studied the behavior of the Pacific sand crab, *Emerita analoga*, a versatile marine invertebrate capable of movement in and on complex terrestrial substrates. We found that the sand crabs used a stereotyped sequence of behavioral primitives to burrow into both saturated and dry substrates with average particle sizes ranging from 0.1 mm to 2 mm. We discovered that as volume fraction of the substrate increased, the average time to burrow increased from 3.7±0.7 s to 5.2±1.0 s. When initiating burrowing, the crabs varied their direction of ingress by altering body pitch angle. Across particle sizes, the dynamics of burrowing were substrate dependent, with pitch at penetration decreasing from 35.6±4.9° to 27.7±5.3° with increasing volume fraction. Drag experiments using constant speed intrusion of small plates showed an increase in penetration force with volume fraction for the substrates tested. We propose a terradynamic model for burrowing behavior based on dynamic substrate response to localized shear and compression. We hypothesize that the crabs modulate body dynamics to exploit low penetration resistance in looser substrates, and reduce shear in substrates near the onset of dilatancy, suggesting effective motion strategies for burrowing in animals and robots.

S4-5 MCINTOSH, RG; Industrial Light & Magic; *calgary@ilm.com*

Using Narrative Film Structure and Technique to Engage an Audience

Many think that science and entertainment are mutually exclusive. But scientists and entertainers share common goals: both want audiences to care about their content, to give it full and undivided attention, and to remember it afterward. Here I discuss how scientists can use the language of film to accurately convey information in a way that makes it accessible to the widest possible audience. Presentation style directly affects how content is perceived and understood. The best filmmakers make their presentation of ideas seamless. They use dramatic tension and narrative thread to keep a viewer enthralled. These same principles apply when presenting data or factual material. The relationship between successive shots or slides can lend dramatic weight to an idea. The way in which you frame and light a character, where you place it in a composition, and which shot follows all convey meaning. I discuss how these techniques can weave an interesting narrative quality into a scientific presentation. A critical goal in any presentation is to elicit suspension of disbelief. In order to make a creature come alive, for example, filmmakers at Industrial Light & Magic (ILM) use extant biological analogues to ground the creature's behavior and physical movement. Scientists use similar methods to reconstruct extinct animals in scientific studies, documentaries, and exhibits. Whether fiction or factual, the goal is to captivate and convince audiences. This effect must be immediate, or the audience will lose interest. With examples from classic films and my own work at ILM, this presentation will demonstrate how small adjustments can make a huge impact on audience reception and retention. These examples will include animation tests that were ultimately used in the final production of the recent ILM film *Jurassic World*, as well as test footage that has never been shown before.

120-1 MCKENNA, AJ*; SANTAMARIA, J; VAN BRUEKELEN, F; Univ. of Nevada, Las Vegas; *austin.mckenna@unlv.edu*

A Direct Test of the Aerobic Capacity Model for the Evolution of Endothermy

A definition of endothermy may be an increase in metabolism which leads to increased body temperatures. Basoendothermic mammals like afrotherians, marsupials, and monotremes maintain lower and more variable body temperatures. Some hypothesize that the evolution of increased endothermy/homeothermy was to allow increased exercise performance. The hypothesis centered on an increased ability to run longer or faster when body temperature was higher. Common tenrecs (*Tenrec ecaudatus*) have extremely variable body temperatures. Animals housed at 12 °C are able to run or swim when body temperature = ~14 °C. We swam tenrecs while monitoring oxygen consumption at ambient/body temperatures at 16, 20, 24, 28, and 32 °C. We calculated the maximal rate of oxygen consumption (Vo_{2max}) at the different temperatures. Vo_{2max} was decreased at lower body temperatures. Endurance (time at 80% of Vo_{2max}) did not change across temperature. We suspect that selection for speed and Vo_{2max} may have contributed to the ability to perform endothermy. However, not all indices of performance are affected equally by temperature.

139-6 MCKENNA, KZ*; NIJHOUT, HF; Duke University; *kenneth.mckenna@duke.edu*

The impact of protein malnutrition on growth and scaling in the rat Rattus norvegicus

During postembryonic development, organismal form changes as parts grow and differentiate. The relative size and shape achieved by body parts is regulated by the tissue specific mechanisms of growth in response to systemic endocrine signals. Intuitively, nutrition ought to play an essential role in relative growth via insulin signaling. However, how variation in nutrition translates to variation in growth and scaling remains understudied. The aim of this study was to obtain insight into how the protein content of an animal's diet affects the growth of body parts and adult scaling relationships. We use an extensive ontogenetic dataset of the growth of bones in rats where littermates were fed either a control diet or a low protein diet. We explore how protein deficiency affects ontogenetic relationships between long bones and cranial bones by fitting of a novel Gompertz allometry equation. Protein content greatly diminishes the rate of growth in all parts, resulting in a change in adult allometry. Further, we demonstrate that when protein is limited, some developing parts compete for available nutrients. This effectively reduces the amount of variation in skeletal growth, suggesting that nutrition can act as a buffer to mask genetic variation in growth.

P2-207 MCLAUGHLIN, G/A*; MILLER, L/A; University of North Carolina at Chapel Hill; *gamclaug@live.unc.edu*

Visualization of Vortex Wake produced by Moon Jellyfish (Aurelia aurita) and Upside Down Jellyfish (Cassiopea)

Moon jellyfish (Aurelia aurita) and upside-down jellyfish (Cassiopea) both mix surrounding fluid through contraction and expansion of their bells, the former for locomotion and feeding and the latter primarily as a method of nutrient exchange. The relatively simple shapes of jellyfish bells and their high swimming efficiency has led to interest in understanding the fluid dynamics and mechanical bell design for applications in mathematical modeling and the design of bioinspired underwater vehicles. We use particle image velocimetry (PIV) and dye visualization to reveal the vortex wake produced by both species in forward swimming, turning, and feeding. PIV is a method of flow visualization where a high-powered laser sheet illuminates seeding particles in the fluid and a cross-correlation algorithm is used to determine the velocity flow field from the particles' displacement. The translucence of moon jellyfish led to relatively successful creation of vector fields showing the train of vortex rings shed in their wake. Dye provided an excellent tool for visualizing the upward jet produced by stationary pulsing of upside-down jellyfish.

P3-194 MCLEAN, CJ*; GARWOOD, RJ; BRASSEY, CA; Manchester Metropolitan University, Univeristy of Manchester; *callum.mclean@stu.mmu.ac.uk*

A Geometric Morphometric Analysis of the Raptorial Appendage of the Whip Spider Damon variegatus (Arachnida, Amblypygi)

Amblypygids are a charismatic group of arachnids that possess a unique pair of ‘raptorial' pedipalps hypothesised to primarily function in prey capture. Little is known regarding intraspecific shape variation within these structures and potential underlying causes, however. A role during courtship and male conflict has also been hypothesised, and sexual selection may therefore contribute to shape change, alongside other environmental factors such as climate zone. This study aims to quantify the contribution of ontogeny, sexual dimorphism and environment to shape change within the raptorial pedipalps of *Damon variegatus* (n=96). Linear appendicular measures were regressed against body length using Type-II regression, and sex differences between slopes tested using the ‘smatr' package in R. 2D geometric morphometrics was carried out on photographed specimens in MorphoJ. Pedipalp tibia length scaled to body size with significant positive allometry (b=1.822 $p<0.001$ r_2= 0.874), yet showed no significant sexual dimorphism (SD). GMM revealed previously undetected SD in pedipalp shape in the tibia segment (p=0.0463), but no significant SD was found in the femur. Significant morphological disparity is also seen in both the tibia and femur between specimens from different climatic zones across Africa. Our results support multiple functions for the pedipalp; significant SD in tibia shape suggests sexual selection as a potential driving factor (either in courtship or male-male confrontation). Yet morphological disparity due to climate conditions also highlights factors other than sexual selection may be acting on pedipalp shape, for example, prey type.

P3-183 MCNAMARA, GPJ*; KIRCHER, BK; COHN, MJ; Univ. of Florida; *griffinmcnamara@ufl.edu*

Digit Development in Anolis sagrei

Tetrapod digits are often characterized by sexually dimorphic digit proportions. For example, in humans and mice, the second digit is generally shorter than the fourth digit, and, as such, the second to fourth digit length ratio (2D:4D) is generally <1. In females, by contrast, the second and fourth digits are of similar length, giving them a 2D:4D ratio >1. This trend has been attributed to differences in embryonic exposure to androgen and estrogen between males and females. Sexual dimorphism in digit ratios has been described across many mammalian species; however, there is limited information about the conservation of this trend across all tetrapods. A handful of studies have described sexual dimorphism in digit ratios in some species of frogs, lizards, and birds. We examined digit development in the iguanid lizard *Anolis sagrei to determine whether sexually dimorphic digit proportions is conserved between mammals and squamates.*

S8-2 MCPHERSON, DR; SUNY at Geneseo, NY; *mcpherso@geneseo.edu*

Sensory Hair Cells: an Overview

Sensory hair cells are responsible for transduction of mechanical stimuli (fluid pressure, fluid movement) in the vestibular, auditory, and lateral line systems of vertebrates. No homologous sensory cells have been identified outside the chordate lineage, making the presence of hair cells almost as diagnostic as the presence of a notochord, pharyngeal slits, or a dorsal, hollow nerve cord. Vertebrate hair cells have a number of specialized physiological qualities, compared to other sensory cells. Transduction occurs by lateral displacement of a group of linked stereocilia, and in some systems the stereocilia are themselves motile. In some other systems, the hair cells are capable of rapid shortening by a process that does not involve actin-myosin interaction. The hair cell-containing sensory organs develop from placodes, and molecular techniques have led to identification of a number of the cellular signals and transcription factors that influence the development of hair cells and which may provide clues about their evolution. The goal of this talk is to provide an overview of hair cell biology for non-specialists.

S8-1 MCPHERSON, DR; SUNY at Geneseo, NY; *mcpherso@geneseo.edu*

Introduction to the Symposium

This will be a brief (10 minute) introduction to the symposium with acknowledgement of sponsors and an overview of the symposium organization.

P1-192 MCTERNAN, M.R. *; ANDERSON, R.A. ; Western Washington Univ.; *matt.mcternan1@gmail.com*

Climate Zones and Thermoregulatory Challenges in a Geographically Widespread Lizard Species.

Species of terrestrial ectotherms such as lizards, with relatively large latitudinal geographic ranges, are subject to spatially varied climatic conditions. At the geographic extremes, lizards may be challenged frequently by environmental temperatures that are either too warm or too cool for effective thermoregulation during the daily activity period. Lizards challenged thermally must either be inactive or accept suboptimal body temperatures (T_b) when active. We documented T_b of field-active (T_{bF}) *Sceloporus occidentalis* from three distinct climate zones in Washington State (the species' northern geographic extreme). We also measured preferred T_b of lizards in a laboratory thermal gradient (T_{bL}), where precise thermoregulation is easily achievable. In the warmest of the three climate zones, in south-central Washington where the daily mean maximum air temperature in mid-summer was 38.9°C (too warm for lizard activity), the mean T_{bF} of lizards was 35.9°C. These temperatures were significantly higher than those in the cool coastal climate, where mean daily maximum air temperature in mid-summer was 27.7°C (rarely too warm for lizard activity) and mean T_{bF} was 35.4°C. Furthermore, from the warm climate, distribution of lizard T_{bF} skewed warmer than T_{bL}. In contrast, T_{bF} of lizards from the coast skewed cooler than the T_{bL}. We infer that field-active lizards from the warmer inland sites of Washington often must accept T_b near the upper limit of their preferred T_b range (36°C), and expect that body temperatures of field-active *S. occidentalis* to the south also skew high. Inexplicably, lizards from the intermediate climate zone (daily mean maximum air temperature in mid-summer of 33°C) exhibited significantly warmer T_{bL} than those from the other two sites despite achieving similar T_{bF}.

78-4 MEHTA, RS*; LAW, CJ; DURAN, E; RICHARDS, E; SANTILLAN, I; MEHTA, Rita; University of California, Santa Cruz; *rmehta2@ucsc.edu*

Effects of Diet on the Evolution of Bite Force in Adult Musteloids

The majority of mammals use biting to ingest prey. Therefore, determining how bite force varies across species is an interesting problem in light of the great ecological and dietary diversity of mammals. Here, we examined bite force in a diverse carnivoran clade, the Musteloidea (weasels, otters, raccoons, and skunks). Musteloids are a tractable group for morphological studies because there is a well resolved time-calibrated phylogeny, musteloid specimens are nicely represented in museums, and, despite their carnivoran habits, many musteloids have evolved diets that vary in the percentage of meat consumed. In addition to hypercanivorous habits, musteloids have evolved mesocarnivores, hypocarnivores, and even herbivorous and durophagous habits. Therefore, we asked whether diet evolution shaped the evolution of bite force in musteloids. We first examined the evolution of diet in musteloids using stochastic character mapping in the program SIMMAP. We find that hypocarnivory is the ancestral diet for musteloids and hypercarnivory solely evolved in the clade Mustelidae. Herbivory, however, evolved three independent times in the red panda, kinkajou, and olingos. We then estimated bite forces in 66 species of adult female musteloids using Thompson's dry skull method and conducted macroevolutionary analyses to examine how diet affects the evolutionary scaling pattern between bite force and cranial size. We found that the evolution of bite force is isometric with respect to the geometric mean of head size across all of Musteloidea. We also discovered that the bite forces of herbivorous species and hypercarnivorous species scaled with positive allometry whereas bite forces of the remaining dietary categories scaled with isometry.

87-5 MEKDARA, PJ*; SCHWALBE, MAB; TYTELL, ED; Tufts University; *prasong.mekdara@tufts.edu*

Neomycin, Streptomycin, and Cobalt Chloride are Ototoxic to All Hair Cells in the Fish Lateral Line System

Aminoglycoside antibiotics are toxic to hair cells of the mechanosensory lateral line system in fish. These antibiotics damage hair cells located in neuromasts and have varying effects between the two physiologically distinct types of neuromasts. Superficial neuromasts are on the skin surface and detect water velocity, while canal neuromasts are located in canals and detect water acceleration. Selectively inactivating one of the two types of neuromasts can show its role in lateral line-mediated behaviors, such as schooling. Gentamycin is commonly used in conjunction with streptomycin to selectively inactivate canal and superficial neuromasts, respectively. However, recent studies have suggested that gentamycin does not have differential effects between the two neuromast types, and that gentamycin is capable of inactivating both types in 24 hrs. To determine the shortest exposure needed to inactivate lateral line hair cells, we tested the effects of neomycin, streptomycin, and cobalt chloride on the lateral line system of giant danios (*Devario aequipinnatus*). We exposed giant danios to 400 µM neomycin, 400 µM streptomycin, or 0.1 mM cobalt chloride and immediately quantified hair cell inactivation using a fluorescent vital stain (4-di-2-asp) at different time points. Our findings suggest that neomycin and streptomycin caused a significant reduction in fluorescence in both superficial and canal neuromasts compared to control fish at similar exposure times. Although these chemicals inactivated superficial neuromasts at a faster rate than canal neuromasts, ultimately both neuromasts types were negatively affected by the aminoglycoside ototoxicity. Cobalt chloride also inactivated hair cells in both neuromast types, but in ~4 hrs. Thus, all neuromasts were inactivated by the three chemicals tested here and not selectively.

P3-30 MEKDARA, PJ*; AMES, AM; MURRAY, JA; CAIN, SD; Tufts University, University of Washington, California State University East Bay, East Oregon University; *prasong.mekdara@tufts.edu*

Multiple Sensory Organs Employ Active Ciliary Suction in Nudibranchs

Nudibranchs rely on mechanosensory and chemosensory detectors for foraging, homing, and location of conspecifics. Despite the studies focused on odor driven behaviors, little is known about the invaginated and ciliated grooves on the oral veil. Prior work indicates that nudibranchs primarily detect odor and flow cues for navigation towards food, mates, and predators with their rhinophores. Our study focuses on the ciliated grooves, a potential boundary-layer sniffing organ that might use similar sensory mechanisms as the rhinophores. Many species of nudibranchs generate ciliary-driven currents between the branches of the clavus of the rhinophore that allows the animal to sample media from up to 5mm away from the organ, likely reducing the olfactory impact of the boundary layer. The ciliated grooves along the oral veil are placed in front of the animal facing downward towards the substrate such that odors trapped in the boundary layer might be actively pulled out of the layer and into the groove. Our results showed that inside the grooves at the lateral ends of the oral veil are dense beds of motile cilia similar to those found on the rhinophores and foot. Video of the ciliated groove using particle image velocimetry shows active particle movement through beating of the cilia. We were able to back trace the nerves from the ciliated groove to the cerebral-pleural complex and the pedal ganglia in *Triopha catalinae*. Nerves from the cerebral and from the ventral, anterior pedal ganglia innervate the oral groove ipsilaterally. Preliminary recordings and stimulation of the Pd7 neurons in the pedal ganglia have given insight to how the particle flow speed down the grooves may be controlled by modulating the beat frequency of the cilia.

73-4 MELIS, J.M.*; LINDSAY, T.; DICKINSON, M.H.; California Institute of Technology; *jmelis@caltech.edu*

Mapping steering muscle activity to 3-dimensional wing kinematics in fruit flies

The extraordinary aerial agility of flies is achieved primarily through the action of 12 pairs of muscles, each innervated by a single motorneuron. A structurally complex wing hinge transforms changes in tension within steering muscles into subtle alterations in wing kinematics, which in turn regulate aerodynamic forces and moments. Understanding this complex transformation between muscle action and wing motion is an essential goal in determining both the neurobiological and biomechanical basis of flight. Our approach is to record the wing motion of tethered flies using high-speed videography while simultaneously capturing changes in muscle activation as reported by a genetically encoded calcium indicator. We use the Gal4/UAS system to express GCaMP6f within the steering muscles and machine vision approaches to determine the time history of activity within each motor unit. By presenting translational and rotational optic flow patterns to the fly, we elicit a variety of virtual maneuvers while capturing wing kinematics with three high-speed cameras. Correlating time history of muscle activation to the wing kinematics yields a model of how the steering muscles control the full 3-dimentional motion of the wing. We plan to combine our analysis with existing data on free flight maneuvers to develop a more comprehensive model of flight control that links muscle activity to body motion.

P1-247 MELOVIDOV, CA*; KIRKHAM, AL; BURNS, JM; Univ. of Alaska, Anchorage, Univ. of Alaska, Fairbanks; *camelovidov2@alaska.edu*

Body Condition and Mass Changes in Weddell Seals: Links to Reproduction and Hair Cortisol Levels

During the Antarctic summer, female Weddell seals (*Leptonychotes weddellii*) expend much of their fat and protein stores while nursing. Recovery of these reserves may influence future reproduction. To determine how mass dynamics differ between postpartum (moms, n=64) and non-reproductive seals (skips, n=32), we measured mass and body condition near weaning, in Nov/Dec, and again during the molt in Jan/Feb. Overall, moms were smaller and leaner than skips in Nov/Dec (mean±SE 282.0±4.6 kg, 31.8±0.5% lipid vs. 437.4±6.7 kg, 38.2±0.5% lipid). After weaning, moms gained weight at an average rate of 0.6±0.1kg/day, accruing primarily lean mass. In contrast, during this same period skips lost an average of 1.0±0.1kg/day, mostly as lipid. This indicates that midsummer is a critical period for mass recovery in moms, but for larger skips, foraging is less important. Surprisingly, despite different mass dynamics, all females ended the summer leaner than at the start. In many species mass loss and reduced lipid reserves are associated with elevations in cortisol levels, which in turn can have negative impacts on reproduction and other life history events. Prior work with this species has shown that serum cortisol is elevated in leaner, post-reproductive females in late summer, but these were single time-point measurements. We will measure cortisol in hair that grew between the two handling periods to assess cortisol levels across a longer time frame. Hair cortisol will be compared to body condition and mass flux, and preliminary results suggest levels are higher in moms than skips. Links between body stores and hair cortisol levels in reproducing and non-reproducing female Weddell seals may indicate physiological trade-offs associated with pupping.

P2-92 MENON, A*; SWADDLE, JP; CRISTOL, DA; College of William & Mary; *amenon@email.wm.edu*

The Effects of Mercury on Sperm Quality and Fertility in the Male Zebra Finch

Mercury is a persistent, globally distributed contaminant that biomagnifies through food webs, causing mortality, reproductive failure and other health concerns in humans and wildlife. Songbirds in some polluted watershed areas have highly elevated blood mercury levels. The effects of mercury on fertility have primarily been examined through correlative field studies and the use of unrealistic doses or modes of mercury exposure under laboratory conditions. To investigate the effects of ecologically relevant levels of dietary mercury exposure on sperm quality and fertility, we presented captive zebra finches with a diet containing mercury at levels comparable to a highly polluted watershed and examined how sperm morphology and motility changed in mercury-exposed animals relative to controls. All birds were then paired with non-exposed females, and eggs were dissected to study whether the ability of the sperm to reach the perivitelline membrane in the egg was affected. Preliminary results suggest that testis size, sperm length and sperm counts were reduced in mercury dosed birds, and fewer sperm cells reached the egg. If exposure to ecological mercury levels reduces male fertility, mercury pollution could reduce the potential gene pool and population viability in regions affected by mercury pollution.

P1-79 MERCADO, N*; BAIOCCHI, T; Univ. of California, Riverside ; *nmerc002@ucr.edu*

Intraspecific Variation in C. elegans Affects Behavioral Response to an Odor Associated with Parasitized Insects

Caenorhabditis elegans Natural Diversity Resource (CeNDR) is a newly emerging tool within the *C. elegans* scientific community. CeNDR is a collection of wild strains of *C. elegans* whose genomes have been sequenced, analyzed, and annotated for all the differences and similarities between the strains. We have used this resource to evaluate the odorant 3-methyl-2-buten-1-ol (prenol), which is associated with insect cadavers that have been parasitized by entomopathogenic (insect-killing) nematodes (known as EPNs). EPNs are repelled by prenol, but other soil-dwelling nematode species, such as *C. elegans*, are attracted to prenol. The divergent set offered by CeNDR is a useful tool to test the effect of natural variation on phenotypic traits such as the behavioral response to odors. The divergent set consists of 12 of the most genetically divergent strains of *C. elegans* available within CeNDR's catalog. Our evaluation of these 12 strains indicated that there is a significant difference in the behavioral response of *C. elegans* to prenol and that this is due to natural variation. With this information, we have moved forward in selecting and testing additional strains from the mapping sets available through CeNDR. This will allow us to identify a genetic locus or loci associated with *C. elegans* ability to detect and respond to prenol. Through this, we hope to utilize conserved biology to better identify how parasitic nematodes might use chemosensory information to avoid already-colonized hosts.

P3-97 MERRELL, EA*; ALLYN, V; MULAWA, EA; DONAHUE, SW; FLORANT, GL; Colorado State University; *eamerrel@rams.colostate.edu*

A Seasonal Comparison of Leptin levels in Bone marrow adipocytes, Blood, and Cerebrospinal fluid in Golden-Mantled Ground Squirrels (Callopermophilus lateralis) and Yellow-Bellied Marmots (Marmota flaviventris.

Hibernation is a process used by some mammals to survive prolonged periods of cold temperatures and lack of food. In preparation, these animals dramatically increase their fat stores, in the form of white adipose tissue (WAT), from summer to autumn. Hibernators stop eating and do not lose bone mass during the hibernation period. Instead, they rely on endogenous energy from WAT during this time. Leptin, a satiety hormone secreted primarily from WAT, has been shown to be involved in the regulation of food intake, body mass, and perhaps bone metabolism. Leptin has been measured seasonally in the blood of several hibernating species, including bears (*Ursus*), bats (*Cynopterus*), marmots (*Marmota*), and ground squirrels (*Callopermophilus*). High blood leptin concentrations during pre-hibernation period were reported across these species, and decreased during the late hibernation season. We sought to gain a better understanding of how these findings compared to the concentration of leptin in other tissue types seasonally in a hibernator. Using a radioimmunoassay (RIA) for leptin, we measured pre-hibernation, hibernation, post-hibernation and summer seasonal concentrations in serum, cerebrospinal fluid (CSF), and tibial bone marrow adipocytes (BMA) of marmots. Using the same RIA, we measured seasonal leptin concentrations in plasma, CSF, and femoral BMA of ground squirrels. We hypothesized that the concentration of leptin in CSF and BMA would not vary with a specific season, however we hypothesized that serum and plasma concentrations would be higher in pre-hibernation and hibernation compared to post-hibernation and summer groups.

S7-1 MERSON, MW; TERC; *martha_merson@terc.edu*

Introducing Science in the Public Eye: Leveraging Partnerships--Credible Collaborators

With stories of struggle and dramatic breakthroughs, science has unlimited potential to interest the public. However, the challenge of communicating science is not trivial. The prevailing attitude toward the study of math and science is that these subjects are hard and boring. There is an urgent need for credible, trusted voices that communicate science in a way that resonates with the public. Whereas academics incur risks to their credibility and suffer consequences from misconstrued or imprecise statements or perceptions of bias or advocacy made in public settings, the situation is quite different for informal educators. By tapping into a network of informal educators, scientific researchers can gain visibility for their research while sidestepping risks to their credibility. This introduction sets the stage for leveraging partnerships with park rangers, museum docents and designers, zoo and aquarium interpreters who are prepared to interact with the public during hundreds of millions of visits a year; just where science stories are most meaningfully told—in the places where members of the public are open to learning. In this symposium, we look at the skills, strengths, and credibility informal educators bring to the endeavor of communicating science to public audiences and explore what it takes for scientists to work productively with informal educators who can give visibility to their research.

P3-15 MERSON, MW*; PARKER-GEISMAN, A; TERC, Independent Consultant; *martha_merson@terc.edu*

Research Briefs: Advantages, Limitations, and Possibilities

Though scientific research often uses cutting-edge methods, requires acts of courage, involves determination and persistence to arrive at startling results, these stories are not always visible or obvious to the public. Equipping interpreters and docents at parks, museums, zoos, and aquariums with up-to-date information on research increases the likelihood that the public will learn of current research and have a chance to discuss its relevance. The research brief is a popular format for conveying the basics of research studies. Though the traditional format has some advantages. Such briefs usually are clear and appropriately detailed, they read as a dry condensed version of a published article or annual report. There are compelling reasons to break with this tradition. Recommendations for research brief content and format follow from an inventory of 85 research briefs available through the National Park Service and interviews with 19 national park professionals. We report on existing briefs in terms of: 1) Reading level and readability 2) Use of images and figures 3) Use of sub-heads and questions. We also share interviewees' responses, highlighting: Interpreters stated comfort level when relying on a two-page document to discuss the research with the public; what is missing as they consider using briefs; and the features they comment on positively. Recommendations will be of interest to those determined to see research prominent in public venues for informal learning and who are committed to creating resources that equip interpreters to bring science into the public eye.

P3-120 METZLER, EJ*; RIVERA FIGUEROA, V; SALAGUINTO, TC; GONZALEZ, VH; PETANIDOU, T; TSCHEULIN, T; AGOSTO RIVERA, JL; HRANITZ, JM; BARTHELL, JF; Salem College NC, University of Puerto Rico, Rio Piedras, Whitman College WA, University of Kansas, Lawrence, University of the Aegean, Mytilene GREECE, Bloomsburg University of Pennsylvania, University of Central Oklahoma, Edmond; *erika.metzler@salem.edu*

Foraging Behaviors Support Dietary Niche Separation of a Generalist Bee and Specialist Bee on Field Bindweed

Systropha curvicornis and *Lasioglossum malachurum* are two bees that both forage on field bindweed (*Convolvulus arvensis*). Observations suggested that *S. curvicornis* forages on pollen and nectar while *L. malachurum* only collects pollen. Our goal was to compare foraging behaviors to test the hypothesis of dietary niche separation between the two species. As a specialist, we expected a shorter handling time per flower for *S. curvicornis* than the generalist *L. malachurum*. We also predicted *S. curvicornis* to have shorter visit times in flowers when either pollen or nectar was absent but *L. malachurum* to have shorter handling times only when pollen was absent. We observed bees under control, pollen removal, and nectar removal conditions. *L. malachurum* had longer handling times than *S. curvicornis* on complete flowers. *S. curvicornis* spent less time on each flower when either pollen or nectar were removed, while *L. malachurum* had lower handling times when only pollen was absent. This supports the hypothesis of dietary specialization between the two species, with *L. malachurum* only collecting pollen from *C. arvensis* while *S. curvicornis* collects both pollen and nectar. Both species show unique foraging behaviors on *C. arvensis*; *L. malachurum* circles the inflorescence while *S. curvicornis* circles and simultaneously taps the inflorescence. Together with temporal niche separation in parallel studies by our group, these two species appear to effectively partition the *C. arvensis* resource.

98-3 MHATRE, N*; SIVALINGHEM, S; MASON, A; University of Toronto, Scarborough; *natasha.mhatre@gmail.com*

Posture Controls The Mechanical Segregation Of Signals In The Body Of The Black Widow Spider

Spiders rely on sensing web vibrations for sexual signalling, prey capture and predator evasion. The sensory organs underlying vibration detection are called slit sensilla: they look like cracks in the spider's exoskeleton and have sensory cells underneath the cuticle. Sensilla crucial to sensing web-vibrations are distributed around leg joints, in collections called lyriform organs. Neurophysiology suggests that lyriform organs are very sensitive to web vibrations but have no frequency selectivity, paradoxically ignoring an important component of information available to them. Neurophysiological measurements, however, effectively ‘disembody' the spider by removing the contribution of the body's mechanics to perception. Black widow females have a striking body-form; their long thin legs support an unusually large pendulous abdomen. Here, we show that in their natural posture, the abdominal mass of black-widow females, interacts with the spring-like behaviour of their leg joints and mechanically determines the frequency tuning of different lyriform organs. We use laser Doppler vibrometry to measure the relative motion of leg segments from a live black widow spider on her web. From this relative motion, we infer joint bending. We use multi-body dynamics modeling to build a model black widow spider, which we verify against our data and then use to study the effect of posture on joint bending spectra. We find that adopting different body postures enables females to alter the mechanical tuning of their joints. Thus posture can be used to flexibly and reversibly direct attention to different components of the web's vibrations. Our results thus emphasize the dynamic loop of interactions between behaviour and perception, i.e. between the ‘brain' and the body.

P2-257 MICHAEL, MJ*; BUBAK, AN; RENNER, KJ; SWALLOW, JG; University of Colorado Denver, University of South Dakota; *michael.greene@ucdenver.edu*

Aggressive Decisions by Pavement Ants (Tetramorium caespitum) During the Formation of Wars with Neighboring Colonies

Ant colonies are distributed systems that are regulated in a non-hierarchical manner. Without a central authority, individuals inform their behavioral decisions by comparing information in local cues to a set of inherent behavioral rules. Collectively, many individual behavioral decisions lead to changes in colony behavior including the decision to be aggressive with neighboring colonies. Pavement ants (*Tetramorium caespitum*) form conspicuous wars with neighboring colonies in which thousands of ants participate. Wars last for many hours and few workers die in the process as because fighting is ritualized. A worker is likely to decide to fight if 1) it has had a recent history of interactions with nestmates and 2) detects a mismatch in nestmate recognition cues, coded in cuticular hydrocarbon profiles, on the cuticle of a non-nestmate ant. We present evidence showing how tactile and chemical cues and social context - isolation, nestmate interaction, or fighting non-nestmates - affect levels of the brain monoamines serotonin (5-HT), octopamine (OA), and dopamine (DA) in pavement ant brains. Interactions with nestmate ants prior to meeting a non-nestmate opponent elevate 5-HT and octopamine levels in a worker's brain. Levels of 5-HT and octopamine above a threshold when an ant detects non-nestmate chemical cues, it is likely to fight the opponent. Dopamine levels are elevated during fighting. We have additional evidence that 5-HT and OA also play a role in the assessment of food quality.

69-5 MICHAELIDES, S. N*; KOLBE, J.J; University of Rhode Island; *smichaelides@uri.edu*

Independent Introductions and Sequential Founder Events Shape Genetic Differentiation and Diversity of the Invasive Green Anole (Anolis carolinensis) on Pacific Islands

Natural range expansions and human-mediated colonizations events usually involve a small number of individuals that establish new populations in novel habitats. In both cases, founders carry only a fraction of the total genetic variation of the ancestral (source) populations. Here we used native and non-native populations of the green anole, *Anolis carolinensis*, to contrast the current distribution of genetic variation in populations shaped by natural range expansion and human-mediated colonization. We analyzed 401 mtDNA haplotypes to infer the colonization history of *A. carolinensis* on nine islands in the Pacific Ocean. We then genotyped 576 individuals at seven microsatellite loci to assess the levels of genetic diversity and population genetic differentiation for both the native and non-native ranges. Our findings support two separate introduction events to the Hawaiian Islands and several western Pacific islands, with subsequent colonizations within each region following a stepping-stone model. Genetic diversity at neutral markers was significantly lower in the non-native range due to founder effects, which also contributed to the increased population genetic differentiation among the non-native regions. In contrast, a steady reduction in genetic diversity with increasing distance from the ancestral population was observed in the native range following range expansion producing a pattern of isolation-by-distance. Contrasting the processes influencing the amount and structuring of genetic variability during natural range expansion and human-mediated biological invasions can shed new light on the fate of natural populations exposed to novel and changing environments.

76-8 MICHEL, KB*; CUFF, AR; ALLEN, VA; HUTCHINSON, JR; Royal Veterinary College; *kmichel@rvc.ac.uk*
Locomotion in Nile crocodiles: Kinematic effects of speed and posture
The study of locomotion in extant crocodylians is important because they are unusual reptiles with a mix of ancestral and derived traits, and because these traits provide insight into the evolution of locomotion in the broader archosaur lineage. Extant crocodylians show a unique ability amongst extant archosaurs by using a spectrum from more sprawling to more erect postures as well as a wide range of symmetrical and asymmetrical gaits. Ten young Nile crocodiles *(Crocodylus niloticus)* ranging from 1.5-7kg were filmed using a combination of light video and fluoroscopy (XROMM) to analyse their locomotion at a range of speeds and gaits, in both straight lines and around bends. These data were supplemented with kinetic measurements from force platforms. We found that the Nile crocodiles showed a range of postures at slow speeds, using a combination of sprawling 'low walks' and belly slides, as well as upright 'high walks'; as in alligators. However, no matter the posture, the duty factor decreased significantly across the range of speeds from 0.1 to 0.7m/s ($P < 0.01$), with no significant difference between fore- and hindlimb duty factors. Our study provides an extensive new dataset on Nile crocodile locomotor dynamics, amplifying our understanding of archosaur locomotion.

P1-189 MIDDLEBROOKS, ML*; CURITS , NE; PIERCE, SK; Univ. of Tampa, Ave Maria Univ., Univ. of South Florida ; *mmiddlebrooks@ut.edu*
The symbiotic chloroplast donor of the kleptoplastic sacoglossan sea slug, Elysia crispata, varies throughout the Caribbean
Sacoglossan sea slugs feed suctorially on coenocytic, green macroalgae and several species store algal chloroplasts for photosynthesis within specialized cells in the digestive tubules. The diets of most sacoglossan species are reported to be highly specialized, with many only feeding on only species of algae. However, several recent studies identifying algal donors using chloroplast genes have found that some slug species use a much wider range of food sources. Furthermore, these molecular based studies found that much of the earlier literature on sacoglossan food sources, which relied on field surveys and slug proximity to algae to determine diet, was incorrect. In this study, we used the PCR determined sequence of the chloroplast gene ribulose bisphosphate carboxylase/oxygenase (rbcL) to identify the algae consumed by *Elysia crispata* from five (Curacao, Barbados, Virgin Islands, Panama and Dry Tortugas) locations throughout its range within the Caribbean. Results indicate that *E. crispata* has a wider diet than previously realized and several new species of algal food were identified for the slug. Diet also was unique among locations. Although *E. crispata* is widespread throughout the Caribbean, it does not show a consistent dietary pattern across its range. This could be due to either local adaptation or an opportunist feeding strategy by the slug.

P1-156 MILES, MC*; SCHUPPE, ER; LIGON IV, RM; FUXJAGER, MJ; Wake Forest University; *milemc16@wfu.edu*
Interactions between sexual selection and morphological constraints shape signal design in woodpecker drum displays
Complex animal displays evolve amidst a tug-of-war between multiple evolutionary processes, each of which has profound consequences on phenotypic elaboration and variability. Chief among these are sexual selection, which typically favors signal elaboration. However, morphological and physiological constraints can simultaneously limit elaboration and variability. How does sexual selection contend with constraint to shape signal design? Studies that address this question typically do so only by assessing how sexual selection or morphological constraint influence signal evolution, but rarely both. Here we examine how constraint and selection differentially act on multiple components of a complex social signal: woodpecker drumming. This highly-physical acoustic display is produced when individuals rapidly hit their bill on a hard surface, and is primarily used in territorial competition by over 200 species worldwide. Every species exhibits a unique combination of drum characteristics encompassing the number of beats in the drum (drum length) and how fast those beats are produced (drum speed). In this study, we explore these two drum characteristics each undergo a unique macroevolutionary trajectory. First, we find that drum speed is constrained by morphology—smaller species can produce faster drums than smaller ones—while drum length is not. As a consequence, drum speed is significantly less variable than drum length on within- and between-species scales. Moreover, intrasexual selection appears to preferentially elaborate drum length, which is unconstrained by morphology. Taken together, these results offer a remarkably clear look at how constraint and selection interact when shaping a complex display: when constraint closes one route to phenotypic elaboration, sexual selection instead operates on a less-constrained signal component.

126-1 MILES, MC*; CHENG, S; FUXJAGER, MJ; Wake Forest University; *milemc16@wfu.edu*
Differential evolution of gestural display complexity across the tropical-temperate divide
Among animals that use displays for courtship and competition, visual signals incorporating gesture— or body movements used specifically for communication—are widespread. These displays vary widely in complexity, from simple limb movements to downright acrobatic performances. However, this is seldom studied on an evolutionary basis. Here we address this by exploring why species use a more or less diverse range of movements in their display repertoire. One factor that should influence how displays evolve is latitudinal biogeography, which indirectly influences sexual selection. This is because the high-latitude temperate breeding season offers a restricted time frame for reproduction, and increasing display complexity is one way to expedite mating decisions. At the same time, a species' social mating system may also influence display evolution, because males of polygynous species undergo more intense competition for mates than monogamous species. In this study, we use the New World blackbirds to explore how biogeography and social mating system each shape gestural complexity. We first find that temperate species evolve more complex gestures than their tropical counterparts, which we attribute to differences in breeding seasonality. Interestingly, these species also evolved in the midst of repeated glaciation events, which can serve as a mechanism for isolation, divergence, and reinforcement. However, social mating system alone does not explain differences in complexity. Altogether, these data offer a first look at how surprising macroevolutionary patterns in an overlooked display mode reveal evolutionary mechanisms at work.

55-5 MILES, DB; Ohio University; *urosaurus@gmail.com*

Becoming small or growing apart different: heterogeneous patterns of body size variation and sexual size dimorphism in response to climate warming

Rising temperatures and shifting rainfall patterns due to climate change have altered the ecological milieu that organisms exploit for resources and reproduction. Many studies have examined actual and potential range shifts or changes in the phenology of species due to climate change. However, few have examined changes in phenotypic traits associated with habitat exploitation. Body size is a key phenotypic trait, because many physiological and ecological attributes scale with size. Several recent studies have shown a decrease in mean body size that has accompanied warmer climates. This pattern has been documented in invertebrates and vertebrate species. In this study, I compared the temporal pattern of body size of the tree lizard (*Urosaurus ornatus*) from a Sonoran desert habitat in southeastern Arizona. I measured boy size (snout-vent length) on males and females at a study site in Saguaro National Park from 1985 - 2017. In addition, I supplemented these data with measurements taken from museum specimens from 1889 - 1980. During the 100+ year interval, average mean maximum and minimum temperatures have significantly increased in nearly all months of the year. Mean body size varied from 1889 - 1980, but showed no specific trend. A segmented regression revealed a shift in body size after 1985. Male tree lizards increased in size, whereas female lizards decreased in size. In addition, the magnitude of sexual size dimorphism also increased. Population size also declined during the 1985 - 2017 period. The changes in body size were consistent with an increase in the frequency and intensity of droughts that began after 1989. The increase in male body size may represent lower intraspecific competition resulting in higher per capita food availability. In contrast, female size may be a result of early onset of reproductive maturity and annual higher mortality.

119-5 MILLER, CW*; MOORE, AJ; University of Florida, University of Georgia; *cwmiller@ufl.edu*

Bug Battles: Previous Experience with Females Affects Male Contest Escalation and Outcome

Dramatic male combat commands attention, yet most males interact peacefully and rarely escalate to physical contests. Male body size and physical condition are known to influence which males compete and male performance. Yet, these are not likely to be the only factors influencing contest investment. Expected reproductive gains should also influence male motivation to fight and to win. Surprisingly little is known about how previous experience with females motivates male contests and shapes contest outcomes. Here, we examined the influence of female quality on male competitive behaviors. We found that low-intensity conflict and dominance were influenced by male size and condition, as predicted by theory. However, we found that escalation to physical combat and winning physical contests was closely linked to previous experiences with females. These results suggest that male motivation and experience with females may be underappreciated factors in the escalation of male-male contests.

P2-160 MILLER, LP*; DOWD, WW; San Jose State University, Washington State University; *luke.miller@sjsu.edu*

A Multi-Modal Sensor System for Monitoring Individual Mussels in Rocky Intertidal Habitats

Highly variable environments can make it difficult to characterize individual organisms' experiences, even for sessile species such as mussels and barnacles. Dense aggregations of the mussel *Mytilus californianus* provide habitat for hundreds of other intertidal species, and these mussel beds may appear relatively homogeneous, but there can be substantial differences in thermal stress and wave stress over spatial scales of only a few mussel body lengths. We have developed a custom datalogger and sensor array that facilitates high resolution, multi-week monitoring of individual mussel status, including internal body temperature, body orientation, and valve gaping behavior. Our open-source hardware design, based on the Arduino software and hardware ecosystem, along with our analysis software, allows us to reconstruct the thermal history and behavioral patterns of individual mussels in natural conditions, and could be extended to include additional sensors such as heart rate monitors in the future. We have used these tools to provide unique insight into the physiological status of mussels. For individuals located only centimeters apart, we observe maximum body temperature differences of up to 14°C, and differences in time spent gaping widely of more than 14 h per day. This type of low-cost, long-duration monitoring system provides individualized data streams for organisms living in highly heterogeneous habitats such as the wave-swept rocky shore, facilitating deeper exploration of organism-environment interactions in the field.

P2-101 MINCEY, KA*; MELTON, AE; HALL, ND; GOERTZEN, LR; BOYD, RS; Auburn University, University of Florida; *kam0048@auburn.edu*

Plastid genome variation within the nickel hyperaccumulator Streptanthus polygaloides (Brassicaceae) and its phylogenetic implications

Streptanthus polygaloides (Brassicaceae) is an annual nickel hyperaccumulator endemic to serpentine soils in the Californian Sierra Nevada. Four morphologically and ecologically diverse morphs of *S. polygaloides* have been described that vary in sepal color, leaf morphology, and height, as well as geographic location. The morphs range from being widespread along northern and central California to being geographically isolated from all other morphs by approximately 100 km. To determine whether the four morphs are genetically distinct, we examined complete plastid genome sequences assembled from high-throughput sequencing data. Genomic DNA samples from eight populations of *S. polygaloides* (2 of each morph: yellow, purple, yellow/purple, and undulate) were sequenced on an Illumina HiSeq platform. Plastid genome sequences were assembled in an iterative fashion with contigs confirmed by mapping original reads back to intermediate stages of assembly. All eight full-length plastid genome sequences were annotated and aligned with various outgroup Brassicaceae. Maximum likelihood and Bayesian analyses were performed with multiple partitioning strategies. Phylogenetic analyses strongly support clades containing purple and undulate samples, although there is a strong geographic signal in the phylogeny overall. Numerous morph-specific plastid SNPs were identified that can be tested more widely across the *S. polygaloides* range with additional sampling.

75-3 MINICOZZI, M*; STUART, F; FINDEN, A; GIBB, AC; Nothern Arizona University; *mrm539@nau.edu*
What are the Anatomical Determinants of Body Shape in Cyprinodontiform Fishes?

Understanding how modifications of the musculoskeletal system generate variation in body shape is key to understanding the evolution of form and function in teleost fishes. The neural and hemal spines projecting from the vertebral centra define the dorso-ventral margins of the posterior body of most teleosts. How are vertebral spines altered to produce variation in body depth among taxa? We hypothesized that variation in body depth is generated by both changes in spine angle (angle of spine relative to vertebral column) and spine length, with more acute angles and shorter spines creating dorso-ventrally "shallower" body types. We quantified the angle the spines create with the vertebral centra in the posterior 40% of the body and the relative length of the spines (spine length/body length) in multiple cyprinodontiform species (killifishes) and regressed these variables on the relative depth of the caudal peduncle (dorso-ventral depth of peduncle/body length), where a positive slope indicates an association between a spine variable and body depth. We found that changes in body shape just anterior to the caudal peduncle can be generated by variation in spine angle, in spine length, or combination of both factors. However, variation in the dorso-ventral boundary of the caudal peduncle is generated by variation of the relative length of the spines, and not through variation in spine angle: shallow caudal peduncles are the result of short vertebral spines. Caudal peduncle depth is also positively associated with spine length in three non-cyprinodontiform taxa; we suggest that spine angle may be constrained in the peduncle, possibly due to mechanical or developmental selective pressures. We also note that killifishes occupy a morphospace wherein multiple combinations of spine length and angle can generate similar overall body shape phenotypes.

68-2 MIROCHNITCHENKO, N/A*; STUBER, E/F; FONTAINE, J/J; Nebraska Cooperative Fish & Wildlife Research Unit, University of Nebraska-Lincoln, Lincoln NE , U.S. Geological Survey, Nebraska Cooperative Fish & Wildlife Research Unit, University of Nebraska-Lincoln, Lincoln; *nmiroch@huskers.unl.edu*
Spatial mismatches between phylogenetic and functional diversity in Nebraska grassland bird communities

Numerous definitions of biodiversity are used in ecological research, each cataloging a different aspect of diversity or measuring systems at different levels of biological organization. While one definition of biodiversity may overlap with other definitions, biodiversity metrics from one perspective should not be used to infer other metrics of biodiversity without understanding the relationships between these metrics across environmental contexts. We investigated how cataloging diversity through ecological versus evolutionary lenses may become spatially disjointed. Here, we surveyed the grassland bird community across Nebraska, USA during the 2016 breeding season using point counts from a stratified semi-random sampling design based on important habitat types. We categorized species assemblages at each survey site using functional and phylogenetic approaches. We used multivariate models to examine the relationship between phylogenetic and functional diversity and demonstrate how the relationship was influenced over land use gradients. Our results will be useful to ecologists interested in context-specific relationships between biodiversity perspectives and wildlife managers interested in conserving areas that maximize both functional and phylogenetic diversity in a declining guild of birds.

P2-190 MISTICK, EA*; CLARK, CJ; Univ. of British Columbia, Univ. of California, Riverside; *emily.mistick@alumni.ubc.ca*
Kinematic control of the wing trill in Allen's hummingbirds (Selasphorus sasin)

Wing trills are pulsed sounds produced by modified wing feathers during flight. We investigated the kinematic basis for the ~9 kHz trill of male Allen's Hummingbird *(Selasphorus sasin).* The wingtip velocity hypothesis posits that trill production is modulated by the airspeed of the wingtip, whereas the wing rotation hypothesis posits that trill production is a function of wing rotation kinematics. To test these hypotheses, we flew six Allen's Hummingbirds in an acoustic (open jet) wind tunnel at flight speeds of 0, 3, 6, 9, 12 and 14 m s^{-1}, and recorded their flight with 'acoustic camera' below, behind, and lateral to the flying bird. The acoustic cameras were a phased array of 40 microphones that used beamforming to paint sound sources onto a camera image. Loudness exhibited a U-shaped relationship with flight speed in all three camera positions. The sound field was loudest perpendicular to the stroke plane. The wing rotation hypothesis was supported by two lines of evidence. The trill is produced during supination, and the trill was up to 20 dB louder during maneuvers than it was during steady state flight in the wind tunnel, across all airspeeds. Support of the wing rotation hypothesis implies that Allen's Hummingbird may have some voluntary control over trill production, meaning they can partially modulate it to be louder or quieter depending on social context. Moreover, the trill may not be correlated with aerodynamic force production, and thus may not signal flight performance during courtship displays produced for females.

12-1 MITCHEL, TW*; GART, SW; KIM, JS; CHIRIKJIAN, GS; LI, C; Johns Hopkins University; *tmitchel@jhu.edu*
Snakes Traversing Large Step Obstacles: Kinematics and Mechanics

Snakes are robust locomotors and commonly traverse a range of obstacles with different topological and frictional properties such as damp rocks or dry logs. Previous studies highlighted the critical role of anisotropic frictional forces in snake locomotion on flat ground. However, our understanding of the mechanics of snake locomotion is more limited in complex 3-D terrains due to a lack of a whole body kinematic description of motion. Here, we study the kinematics and mechanics of the variable kingsnake (*L. mexicana*) traversing high step obstacles up to $^1/_4$ body length (L). We applied a recently developed method to quantify continuous body kinematics in 3-D. This allowed us to apply a planar force model (Hu et al., 2009) to calculate frictional forces on the parts of the body in contact with the terrain and inertial and internal forces along the entire body. We found that frictional and internal forces (F_f, F_{int} ~ 10^{-4} N/m) during movement were an order of magnitude greater than the inertial force acting on the animal (F_{iner} ~ 10^{-6} — 10^{-5} N/m). This suggested that the animal moved nearly quasi-statically and that forces were transduced directly to velocities rather than accelerations, similar to previous observations on flat ground. When climbing onto a step, the animals used the anterior body to pull and the posterior body to push itself. Forward frictional forces in the direction of the snakes' motion were produced at bands of ground contact (L_{cont} ~ $^L/_{10}$) that propagated down the body from head to tail, with an average contact time of half a second and temporal frequency of 1.6 Hz. Our study suggested that animals modulate body kinematics to use anisotropic friction to traverse 3-D obstacles, and provides guidance for snake-like robots to traverse terrains such as building rubble and landslides.

P3-233 MITCHELL, TS*; WARNER, DA; Auburn University; *tsmitchell09@gmail.com*

The Effect of Density and Timing of Hatching on Early Life Phenotypes and Survival of Anole Lizards

Intra-specific competition is strongly influenced by population density, and can have profound effects on individuals and populations. For example, spatial and temporal variation in population density can influence phenotypic variation via numerous mechanisms (e.g. natural selection, phenotypic plasticity). Prior research from long-term population monitoring at our field site indicates that adult lizard density strongly influences hatchling survival and patterns of natural selection. Additionally, laboratory experiments show hatchling lizards modify behaviors in response to adult densities. In this large-scale field experiment, we spatially manipulate adult population densities, and leverage naturally occurring temporal changes in hatchling density to evaluate the effects of conspecific densities on early life phenotypes and survival in *Anolis sagrei*. We released marked hatchling lizards onto small islands where we experimentally manipulated the population densities such that there were either high or low densities of adult anoles. We released these hatchlings early in the season, when hatchling densities are naturally low, and later in the season, when hatchling densities are naturally high. We sampled the populations at the end of the breeding season (prior to winter) and again the following spring. These data will allow us to investigate the importance of timing of hatching, and patterns of growth and selection under differing population densities.

103-6 MITCHELL, JM*; NICHOLS, SA; University of Denver; *yinnismc@gmail.com*

Novel Cell Adhesion Mechanisms in Sponge Tissues

A fundamental requirement for multicellularity is cell adhesion. This includes mechanisms by which cells adhere to each other, and to their secreted extracellular matrix (ECM). Two well characterized adhesion complexes in animals include: 1) adherens junctions (AJs), which are involved in cell-cell adhesion and minimally composed of cadherin receptors, p120-, α and β-catenin, and 2) focal adhesions (FAs), which are involved in cell-ECM adhesion and include proteins such as integrins, vinculin, paxillin, talin and focal adhesion kinase (FAK). Dynamic regulation of AJs is critical for developmental morphogenesis and tissue homeostasis, whereas FAs are dynamically regulated in single- and collective cell migration. The molecular components of AJs are widely conserved in animals, and largely absent in non-animals. In contrast, the molecular components of FAs have more ancient origins and can be traced to animal outgroups, and beyond. From an experimental perspective, much less is known about how AJ and FA components function and are regulated in non-bilaterian animals. A recent study of the AJ protein β-catenin in the sponge *Ephydatia muelleri* found that it localizes to AJ like structures at cell-cell contacts, but also to FA-like structures at the cell-ECM interface. This led us to further examine the localization patterns of the focal-adhesion proteins, vinculin and FAK in sponge tissues. Surprisingly, we find evidence that these canonical FA-components co-localize with β-catenin at both cell-cell and cell-ECM contacts, suggesting fundamental differences between the organization and molecular composition of cell junctions in tissues of sponge compared to bilaterians. Additionally, we pharmacologically perturb FAK function *in vivo* to test for disrupted cell adhesion and cell migration phenotypes.

82-7 MITCHELL, AE*; MARTIN, TE; MITCHELL, Adam; University of Montana; *adamemitchell@gmail.com*

Patterns and Causes of Tropical Montane Life Histories: An Observational and Experimental Study Using Birds

Life history theory describes a slow-fast continuum within and across species. Species and individuals living at higher elevations often have slower life histories than relatives at lower elevations. This pattern mimics the wide-spread and well-studied pattern across latitudes, but hypotheses for latitudinal life history variation do not explain the variation observed across elevations. We first provide data verifying this pattern using two communities of birds at two continuous but disparate field sites (1500m asl and 3200m asl), and second, experimentally test a novel hypothesis for the causes of this pattern. The harsh weather hypothesis states that slow life history traits at high elevations are caused by parental constraints due to cool ambient temperatures exacerbated by wetting from rainfall. This harsh weather requires parents to spend more time warming offspring, resulting in less time available for food provisioning. Reduced provisioning rates may cause delayed post-natal development, a key life history stage. We tested this hypothesis by adding supplemental heat to nests of Mountain Blackeyes (*Chlorocharis emiliae*) at 3200 m asl on Mt. Kinabalu, Malaysian Borneo. Our results support the harsh weather hypothesis showing that heated nests cause lower adult brooding and increased nestling provisioning rates. Thus, our results explain one mechanism by which life history traits of high elevation birds fall closer to the slow end of the life history continuum than those at lower elevations.

P1-152 MIYAMAE, J.A.; Yale University; *juri.miyamae@yale.edu*

Waiting for Whiskers: Comparative Morphology of the Trigeminal Canal and a Scenario for the Evolution of Facial Musculature in Mammals

Facial muscles are fundamental to the mammalian experience: swiveling the ears, twitching noses and whiskers, suckling, and communication through facial expression are all dependent on the presence of these muscles. However, the identification of when these soft-tissue structures appeared in the fossil record is a challenge. MicroCT scan reconstructions of the neurovascular canals hosting the maxillary and mandibular branches of the trigeminus (cranial nerve V) in a sample of both extant and fossil taxa reveal changes in morphology corresponding to a hypothesized ancestral, stem mammal transitional, and crown mammal derived conditions. I propose that (1) a concentration of tactile sensory ability at the rostral end of the snout characterizes the stem mammal transitional condition and (2) that the reduction in number of trigeminal nerve foramina and subsequent appearance of the infraorbital foramen near the crown mammal node is an osteological correlate for the presence of specialized whiskers (i.e., mystacial vibrissae), that are actively moved by facial muscles during tactile exploration. The results of this comparative morphological study are placed within the broader context of research on the biomechanical properties of nerves, vertebrate development, and mammalian evolutionary history.

24-4 MIYASHITA, T*; PALMER, AR; University of Alberta; *tetsuto@ualberta.ca*

Testing cyclostome-based models for vertebrate ancestry

As the only living jawless vertebrates, cyclostomes (hagfish and lampreys) are a crucial taxon to infer conditions at the crown vertebrate node. The Hagfish Model accepts hagfish as nesting outside other vertebrates and interprets the morphology as primitive, whereas the Ammocoete Model compares ammocoete larvae of lampreys with amphioxus to derive a filter-feeding vertebrate ancestor.

The Hagfish Model has been challenged by molecular inferences that support cyclostomes as a clade. Aided by synchrotron radiation scanning of preserved soft tissues, I report a new fossil from the Cretaceous of the Middle East. This new taxon nests within the hagfish crown group. The exquisitely preserved soft-tissue anatomy elicited revision of morphological characters in hagfish that were considered primitive. A new phylogenetic analysis recovered cyclostomes as a clade. This topology falsifies a prediction of the Hagfish Model.

The Ammocoete Model is non-parsimonious under the current chordate phylogeny, with tunicates as an immediate vertebrate outgroup and hagfish as sister to lampreys. If the model is correct, the filter-feeding larval stage should have been present in stem lampreys. I test this prediction using stem lampreys from the Devonian southern polar region. In this taxon, skeletal correlates of filter feeding are lacking across all ontogenetic stages. Instead, the larvae have correlates of predatory habits. The absence of a filter-feeding larval stage in this stem lamprey suggests a secondary acquisition of a filter-feeding larval stage in the living lamprey lineage.

Therefore, the new fossil evidence rejects both the Hagfish and Ammocoete models to reconstruct the last common ancestor of all vertebrates. Cyclostomes form a clade under the new analysis, and a filter-feeding larval stage likely represents a secondary acquisition.

36-2 MOBERLY, IT*; MOON, BR; Univ. of Louisiana at Lafayette ; *itm3905@louisiana.edu*

Interplay between Setae and Locomotor Kinematics in an Arboreal Lizard (Furcifer oustaleti)

Movement through arboreal habitats is particularly challenging, as these habitats contain complex arrangements of perches varying in diameter, incline, and spacing. Due to the risk of falling, maintaining stability is of the primary importance in arboreal locomotion. Chameleons are largely arboreal specialist and possess a diversity of characteristics that enable them to maintain stability while smoothly moving through their complex environments. The substrate-contacting surfaces of their zygodactylous feet contain friction-enhancing setae that provide resistance to toppling movements. To explore the functional significance of setae in arboreal locomotion, I covered the setae with ceramic microspheres to block their function. I recorded Oustalet's chameleons (*Furcifer oustaleti*) moving across perches of different diameters, inclines, and hardnesses before and after covering their setae. I assessed the conditions which brought about the largest changes in locomotor kinematics, providing insight into the perch conditions which setae provide the greatest benefit to maintaining stability. I also explored the kinematic responses of chameleons to having their setae covered, to assess how they maintain stability without functioning setae.

P1-27 MOBLEY, RB*; BOUGHMAN, JW; Michigan State University; *mobleyro@msu.edu*

Ecology and Evolution in the Sensory Morphospace of Threespine Sticklebacks

Sensory systems evolve under the influence of other senses, as well as the external environment. Because sensory systems can be physiologically expensive to produce, use and maintain, selection for the elaboration of one sensory system may be coupled to the degradation of another. However, because ecological factors may have selected for the benefits of multimodal perception, different sensory systems may be expected to be correlated in their evolution. This study aims to determine how sensory systems evolve with each other under different ecological pressures. Morphological metrics of the visual, olfactory, and lateral line systems of marine, as well as lacustrine benthic and pelagic populations of threespine sticklebacks were obtained and used to analyze the relationships between sensory systems and the environment. We hypothesized that: 1) sensory characters of freshwater fish would be distinct from that of marine fish, which are characteristic of the ancestral stickleback condition; and further 2) pelagic fish would show elaboration of visual senses and reduction of non-visual senses, relative to the ancestral condition, to maximize use of the light-rich environment. Benthics were predicted to show the opposite trend, to compensate for the reduced availability of visual information. Initial data indicate a positive correlation of the visual and mechanosensory systems in all habitats, and benthics evolving enhanced visual and mechanosensory systems relative to other habitats. No significant differences in the chemosensory system have been found. This suggests that while divergence of some sensory systems has occurred due in part to variation in the environment, rather than trade-off visual and non-visual senses, the correlated evolution of visual and mechanosensory systems occurs independently of the olfactory system.

P2-72 MODY, M; MAAN, R*; BANERJEE, R; DEYARMIN, J; HECKMAN, R; HOLSER, R; COSTA, D; KHUDYAKOV, J; University of the Pacific, University of California, Santa Cruz; *jkhudyakov@pacific.edu*

Blubber Proteome Response to Fasting in Adult Female Elephant Seals

Marine mammals such as elephant seals (*Mirounga angustirostris*) are unique in their ability to fast from food for months while undergoing energetically demanding processes such as molting and reproduction on land. To gain insights into energy provisioning during fasting, we examined protein expression in the energy-rich inner blubber tissue layer collected from adult female elephant seals at the beginning and end of their month-long molting fast. We developed tissue lysis and protein extraction methods for marine mammal blubber shotgun proteomics using phenol-chloroform. Changes in protein abundance and composition in blubber during fasting were analyzed using isobaric labeling and orbitrap mass spectrometry. We were able to identify and annotate hundreds of proteins using a blubber transcriptome as reference. These included proteins involved in hormone signalling pathways, such as glucagon, estrogen, insulin, and aldosterone, carbohydrate and fatty acid metabolism, protein digestion, absorption, and processing, biosynthesis of amino acids, immune signaling, and many others. This work lends insights into metabolic homeostasis during fasting in adipose tissue, validates previous transcriptome analyses, and yields protein sequence information for further targeted assays.

140-8 MOFFITT, M*; NATESAN, S; REHMAN, F; AHEARN, GA; University of North Florida, Cornell University; *gahearn@unf.edu*

Preliminary Study: Invertebrate Primary Cell Culture on 3D Collagen Matrices

A keystone species, the North Atlantic lobster, *Homarus americanus*, is a cold water invertebrate that is important fundamentally and commercially. Due to the lobster's anatomical and physiological complexity, the transepithelial transport processes for any nutrient, ion, or heavy metal cannot be studied with ease. Therefore, dissociation of the organs, i.e. hepatopancreas, antennal gland, into cellular suspensions that can form functional confluent monolayers *in vitro* would provide a new method to study the physiological functions of nutrient and ion absorption and transepithelial transport. Cell culture would provide a technical means by which complex invertebrate organs can be studied in relation to the transcellular transport properties of the epithelial cells that comprise the organs. In this preliminary study, 3D culture techniques, cell dissociation techniques, cell viability, and cell density seeding were investigated to develop the best method for a successful crustacean cell culture with a functional confluent monolayer. It was found that enzymatic dissociation, rather than mechanical dissociation, yielded more viable cells that were likely undergoing mitosis, forming functional junctions with neighboring cells, and pseudopods on 3D collagen substrata. Cell density also plays an important role in the development of a confluent monolayer, in which cells must be seeded densely to form functional junctions. With these investigations, the functional analysis of nutrient absorption in cultured monolayers arranged on a nylon screen placed in an Ussing chamber that can separate the monolayer's apical and basal membranes can tell us the nature of solute movement across the cell layer and what processes regulate those transport events.

123-4 MOHAGHEGHIAN, EM*; WANG, NW; Univ. of Illinois at Urbana-Champaign; *mohaghe2@illinois.edu*

Quantifying Compressive Forces Between Living Cell Layers and Within Tissues Using Elastic Round Microgels

Increasing evidence suggests that mechanical forces play critical roles in development, physiology, and diseases. Reports have implicated stresses to be important in regulating cell and tissue functions in embryogenesis and in tumors. However, no methods exist that can quantify compressive stresses between living cells or in living tissues in situ. Using self-designed microfluidic channels, we generated cell-sized, fluorescent nanoparticles-labeled, mono-disperse elastic microspheres made of Arg-Gly-Asp conjugated alginate hydrogels (elastic round microgels, ERMs). Using confocal fluorescence microscopy to image ERMs after they were trapped between cell layers or in a cell colony, we generated 3D displacement maps with fast iterative digital volume correlation and calculated strains, normal and shear tractions exerted on the ERMs. We found that average compressive tractions are ~570 Pa between cell layers and are ~360 Pa in a cell colony of tumor-repopulating cells (TRCs) grown in a fibrin gel of 400 Pa in elastic stiffness. Surprisingly, the compressive stresses were substantially heterogeneous on the ERMs within a seemingly uniform melanoma colony and did not increase with the colony size of the TRCs. Substantial local compressive, tensile, and shear stresses were exerted to an ERM by cells of developing zebrafish embryos several hours post fertilization. Our findings suggest that this ERM method is useful for quantifying stresses (compressive, tensile, and shear) between living cell layers and in living tissues.

71-2 MOHAMED, A; STOWERS, S; WEIKEL, A; COLON, E; CLARK, K; DAMERON, M; REDMOND, S*; Radford University; *sredmond3@radford.edu*

Vespa amino acid mixture enhances the proton motive force leading to oxidative stress which is reversible by antioxidants and uncouplers

Vespa amino acid mixture (VAAM) is a mixture monomeric amino acids mimicking the salivary secretions of larval *Vespa mandarinia* which enhances endurance capacity and ATP production in many eukaryotic species. We have demonstrated that while VAAM does increase the ATP production of mitochondrial and cellular isolates and the endurance of live organisms, high doses of VAAM limit the survival of mitochondria, cells, and organisms. We propose that this is due to increased oxidative stress leading to mitochondrial degradation and activation of apoptotic pathways. *Brassica oleracea* mitochondrial isolates exposed to high or moderate doses of VAAM initially increase export of protons, but lose the ability generate the proton motive force and maintain ATP production within 20 minutes. VAAM treated *Saccharomyces cerevisiae* significantly accumulate hydrogen peroxide within 5 minutes, followed by shifts in NAD^+/NADH and activation of caspase signaling within 30 minutes. Addition of &alpha-tocopherol limits the negative impacts of VAAM on these markers without a significant reduction in ATP production. Combining VAAM treatment with 2,4-dinitrophenol or sodium azide, both uncouplers of the proton motive force, also reduces the negative impacts of VAAM on mitochondrial and cellular markers. This is surprising, as mitochondrial membrane uncouplers have well established toxic effects, which seem to counteract the toxic activity of VAAM. Taken together, these findings suggest that VAAM increases the rate of proton transport, resulting in an increase in oxidative phosphorylation and a level of reactive oxygen production which damages mitochondrial membrane structure. The mitigation of these effects by mitochondrial membrane uncoupling agents suggests VAAM has the capacity to supercouple the proton motive force with the activity of ATP synthase.

22-3 MOHREN, TL*; EBERLE, AL; FOX, JL; DANIEL, TL; Univ. Washington, Seattle, Case Western Reserve, Cleveland; *danielt@uw.edu*

Spike timing in halteres reflects gyroscopic forces

The halteres of flies are reduced hindwings possessing several fields of mechanosensory campaniform sensilla at their bases. Halteres beat at the same frequency as wings, and this motion makes them susceptible to gyroscopic forces and deformations during body rotations. Theoretical and experimental evidence suggests that the campaniform sensilla send information about these forces to motoneurons for use in flight control. We modeled the haltere of a crane fly using finite element analyses and verified two critical emergent deformations that arise from gyroscopic forces: (1) a lateral deflection of the haltere and (2) a previously unreported torsional deformation that arises when the haltere is represented as a distributed mass. Using this structural model, combined with experimentally determined neural encoding of strain by campaniform sensilla, we predict spatial and temporal patterns of neuronal firing at the base of the haltere. Our results show that there is a significant spike timing difference of sensilla around the circumference of the haltere. Along the dorsal and ventral surfaces, the timing differences are below the experimentally determined estimates of the jitter of spike time arrival (approximately 0.2 ms). However, along the lateral margins we see timing difference arising from gyroscopic forces on the order of 5 to 10 ms for an orthogonal body rotation of 10 rad/s. The mechanics of the haltere can significantly change this spike timing. These results suggest that spike timing differences of campaniform sensilla, in addition to directional selectivity, can contribute to gyroscopic force sensing.

S3-6 MOJADDIDI, H; RE, C; PEREZ, J; TACDOL, A; FISER, Z; TRONTELJ, P; PROTAS, M*; Dominican University of California, University of Ljubljana; *meredith.protas@dominican.edu*

Development and genetics of eye loss in the crustacean, Asellus aquaticus

Cave animals are striking and amazing animals with common features such as reduced eyes, reduced pigment, elongated appendages, and enhanced sensory systems. Few cave-dwelling species are amenable to genetic and developmental techniques making it challenging to ask questions about the evolution of these traits. To address this limitation, we have been developing *Asellus aquaticus*, an isopod crustacean, as a developmental and genetic model. *Asellus aquaticus* has both cave and surface dwelling forms that vary in many characters such as eye size, pigmentation, and number of antennal segments. Our first goal was to utilize comparative embryology to examine when in development these different morphologies came about. We found that eye loss, pigment loss, increased number of antennal articles, and different morphologies of chemosensory sensilla are already established by the end of embryogenesis. Our second goal was to take advantage of the multiple cave populations of this species and ask whether the same or different regions were responsible for the evolution of eye and pigment traits in different cave populations. Of the two populations examined so far, we found that the same regions are responsible. Future studies will examine additional populations to see if the same regions are commonly associated with eye and pigment loss. In summary, we have shown that *Asellus aquaticus* is an excellent species to study the developmental and genetic basis of cave specific characteristics and contains all of the necessary characters to more completely dissect the developmental and genetic mechanisms responsible for these evolutionary changes.

P3-128 MOLLOY, AR; Whitman College; *arose.molloy@gmail.com*

Sensory modalities used in predator avoidance by frugivorous and nectarivorous bats

Predator detection and avoidance are important behaviors that dictate the success of animal species and that can alter foraging behavior. Frugivorous and nectarivorous bats play key roles in tropical ecosystems as both seed dispersal agents and pollinators, but little is known about how they identify the presence of predators. I investigated the use of vision, echolocation, and olfaction by frugivorous and nectarivorous bats in Monteverde (Costa Rica) in detecting predators while foraging for food. Nectar and fruit feeder stations with and without predator cues were set up in an indoor flight cage. Bat visitation and nectar consumption at each feeder were recorded during ten 10-min observation periods. Predator cues included a clay model snake and odors in leaf bedding from an eyelash palm pit viper cage. Based on both the number of visits and quantity of nectar consumed, nectarivorous bats avoided feeders with either visual or olfactory predatory cues, whereas fruit bats appeared to rely more heavily on olfaction than vision or echolocation for predator avoidance. These findings suggest that the bats use the same sensory modalities to detect predators as they do to locate food.

10-3 MONGEAU, J.-M.*; FRYE, M.A.; University of California, Los Angeles; *jmmongeau@psu.edu*

Neural Correlates of Saccade Control Algorithms in Drosophila

Like other visually active animals, flies generate rapid saccadic movements to control and stabilize their gaze. Saccades enable evasive maneuvers to a threat as well as orientation maneuvers to fixate upon a goal. How rapid body saccades are controlled, and how their valence is determined, remains elusive. We studied visually-guided saccades in rigidly- and magnetically-tethered *Drosophila*, thereby enabling precise control of a visual stimulus in open- and closed-loop conditions, respectively. We presented a moving bar in open-loop and discovered that changing the vertical size caused a switch in saccade direction relative to the stimulus. Correspondingly, in closed-loop, a moving long vertical bar elicited sustained bouts of fixation saccades towards the bar, whereas a short object elicited aversive saccades away from the object. Bar fixation saccades were narrowly tuned to specific dynamical properties of bar motion. To study the neural circuitry that implements saccade control algorithms, we used two-photon excitation imaging to screen the major motion vision pathways within the fly brain for activity that matches the stimulus dynamics that trigger saccades. Our results correlate the activity of a remarkably small subset of previously uncharacterized cells within the lobula with spatial and temporal dynamics required for visual saccade control, and indicate that fixation and aversive saccades are mediated by parallel visual circuits. We show that simple behavioral algorithms and parallel neural circuits underlie visually-guided saccade control in *Drosophila*.

P1-275 MONTEJO, EA*; MAIA, A; TAFT, NK; University of Wisconsin - Parkside, Eastern Illinois University; *taft@uwp.edu*

Material properties of the fin rays among the paired and median fins of shortnose gar

Shortnose gar (*Lepisosteus platostomus*) are basal actinopterygian fishes that retain a primitive pattern of fin placement. However, the structure of the fin rays or lepidotrichia is similar to that of more modern fishes. Fin function in all ray-finned fishes is largely determined by properties of the bony, segmented fin rays. Here, we explore variation in flexural stiffness among the paired and median fins of the shortnose gar, excluding the caudal fin. We combine morphological data from CT scans with three-point bending tests to understand the relative contributions of fin ray shape and size to the stiffness of the fin rays of shortnose gar. We predict that stiffness will be largely influenced by size and shape of the fin rays, as well as their position within the fin. The results of the three-point bending tests reveal that the pelvic fin rays of the shortnose gar are the most stiff. In all fins but the pelvic fin, the flexural stiffness of the fin rays decreases moving from the leading to trailing edge of the fin. The pectoral fin rays are significantly less stiff than the other fins, and also had the smallest diameter. The flexural stiffness of the dorsal and anal fins was not significantly different from one another. Shape is also an important factor in determining stiffness. We measured the cross-sectional shape of the fin rays using micro computed-tomography (CT) scans in order to calculate second moment of area. This will allow us to assess the relative contributions of shape and size to overall fin ray stiffness. We can then compare the relative stiffness both within and among the fins to data for other, more derived fishes to get a better understanding of how fin ray morphology and function has changed over evolutionary time.

S9-9 MONTOOTH, Kristi L.*; BUCHANAN, Justin L.; University of Nebraska-Lincoln; *kmontooth2@unl.edu*

A Mitochondrial Contribution to Immune Function and Life-History Tradeoffs

Mitochondria require both mitochondrial- and nuclear-encoded genes to provide the energy for eukaryotic development and performance. It is therefore not surprising that selection on mitochondrial function shapes the evolution of both mitochondrial and nuclear genomes. Given its central role in the energy budget of eukaryotic organisms, there is reason to expect that variation in mitochondrial function will contribute to the evolution of life-history traits. Furthermore, to the extent that limiting resources can generate tradeoffs between life-history traits, defects in mitochondrial function that limit energy stores may reveal life-history tradeoffs even when nutrient resources in the environment are not limiting. We review the literature for mitochondrial effects on immune function, and present evidence that defects in oxidative phosphorylation caused by mitochondrial-nuclear incompatibility compromise immune function and generate tradeoffs between immunity and fecundity in Drosophilid flies. Given the unique genetics and biology of mitochondria, we also expect that gene-environment and gene-gene (i.e., epistatic) interactions will govern genotype-phenotype relationships for traits that depend upon mitochondrial function. We review the evidence that mitochondrial effects on life-history traits are complex and involve mitochondrial-nuclear epistasis, environmental sensitivity, and life-stage, sex and tissue specificity. Finally, we discuss the impact of complex mitochondrial genotype-phenotype relationships on mitochondrial evolution, as well as implications for investigations in eco-immunology.

P1-294 MONTUELLE, SJ*; OLSON, R; DAVIS, JS; CURTIS, H; WILLIAMS, SH; Ohio University, High Point University; *willias7@ohio.edu*

Pitch, Roll and Yaw: Hemimandible Movements and Symphyseal Function During Chewing in Musteloid Carnivorans

The mandible of most mammals is comprised of two hemimandibles that are united anteriorly at a symphyseal joint. Although mobile symphyses, as opposed to fully ossified and fused symphyses, are the most common symphyseal morphology across Mammalia, the function of the joint during feeding remains unclear for the vast majority of species. Here, XROMM was used to quantify the degrees of freedom of movement of each hemimandible with respect to the skull (i.e., translations along and rotations around the anteroposterior axis, the dorsoventral axis and the mediolateral axis) in 3 carnivoran species with unfused mandibular symphysis: *Mephitis mephitis* (skunk), *Mustela putorius furo* (ferret), *Procyon lotor* (raccoon). Movements are also evaluated relative to the phases of the gape cycle. The classic phases of the gape cycles are observed in all species (fast-closing, power stroke, slow-opening and fast-opening), although the power stroke is not always distinguishable in each cycle. Cycle duration, and thus chewing frequency, is similar, but phase durations vary significantly between species. Not surprisingly, dorsoventral rotation of both hemimandibles at the temporomandibular joint (pitch) producing jaw depression and elevation dominate chewing movements. Rotation about the anterior-posterior axis (roll) is observed, with maximum roll resulting in eversion of the alveolar process occurring during jaw closing. Some anterior-posterior translation (i.e., protraction retraction) of each condyle occurs, but there is no rotation around the dorsoventral axis (yaw), contrary to what has been observed in species with fused mandibular symphyses. In the species examined, the unfused symphysis may allow independent movements of the hemimandibles to facilitate alignment of the teeth during fast-closing and occlusion during the power stroke.

P3-254 MONUKI, KS*; SORTE, CJB; BRACKEN, MES; Univ. of California, Los Angeles, Univ. of California, Irvine; *ksmonuki@gmail.com*

Mussel Condition Across Environmental Stress Gradients in New Zealand

Rocky intertidal organisms experience varying levels of environmental stress along elevational (tide height) and oceanographic (geographic) gradients with implications for survival and patterns of abundance and distribution. Given potential changes in food availability and physical stress under climate change, it is important to determine how the physiological conditions of intertidal species are affected by environmental stressors. Mussels are critical foundation species in rocky intertidal ecosystems, as they are a trophic link between primary production and predators and provide habitat to associated intertidal organisms. We determined mussel condition across multiple stress gradients in New Zealand, where four co-occurring mussel species (*Aulacomya maoriana*, *Perna canaliculus*, *Mytilus galloprovincialis*, and *Xenostrobus pulex*) comprise a uniquely diverse intertidal assemblage. We measured three metrics of mussel condition (growth rate, gonadosomatic index [GSI], and tissue C:N ratio) across two stress gradients (temperature represented by tide height and food availability represented by chlorophyll concentration). We hypothesized that as stress increased, condition would decrease. We found that growth rate was the only metric that varied in the expected direction, indicating that GSI and tissue C:N ratio are likely influenced by other factors. A temporal difference may also help explain our results: growth rate was measured - and integrated environmental impacts - over a year while GSI and C:N ratio were measured only once as "snapshots" of mussel condition. Our results suggest measurements that describe organismal performance over longer time scales (e.g. annual growth rates) are better indicators of potential impacts of climate change on these marine species.

P3-111 MONZON, R/I; Saint Xavier University; *monzon@sxu.edu*

Detection of Spinophilin (Neurabin-II/PP-1) and Glyceraldehyde 3-Phosphate Dehydrogenase (GAPDH) mRNA Transcripts in Brain Regions of the Red-Sided Garter Snake Thamnophis sirtalis parietalis

The increasing number of newly sequenced genomic databases for both vertebrate and non-vertebrate animal species has greatly advanced our ability to perform genetic analysis with comparative studies. In this study we perform bioinformatic analysis of the genomic sequence from the garter snake species (*Thamnophis*) to find homologous sequences of mammalian genes to derive targeting primers used in the detection of mRNA levels using reverse-transcriptase polymerase chain reaction (RT-PCR). In particular, we derived targeting primers for sequences homologous to the Spinophilin (Neurabin-II/PP-1) gene, which encodes a protein involved in dentritic spine formation in post-synaptic neurons, and Glyceraldehyde 3-phosphate dehydrogenase (GAPDH), an enzyme involved in the glycolysis pathway. RT-PCR analysis was carried out on total RNA isolated from different brain regions of the Red-sided Garter snake, (*Thamnophis sirtalis parietalis*), to determine differential expression of Spinophilin that correlates with different levels of dentritic spine formation. GAPDH primers were then used to determine levels of constitutive gene expression, serving as a normalizing control for Spinophilin expression. By utilizing bioinformatic tools to derive additional targeting primers, we can greatly expand the repertoire of genetic targets for study in the Red-sided Garter snake.

P3-274 MOODY, T*; FAGAN, A; ST. JOHN, P; MASS, M; SUNY New Paltz; *moodyt1@hawkmail.newpaltz.edu*

Quantifying the Retention of BPA in Regenerating Planaria

Bisphenol A (BPA) is a xenoestrogen found in the environment in various concentrations, originating from wastes like cleaning and beauty products, pharmaceuticals, and plastics. We have used high performance liquid chromatography (HPLC) with fluorescence detection to quantify the amount of BPA absorbed by planarian, a model organism, as BPA absorbs light in the ultraviolet range and fluoresces upon UV excitation. We have extracted on the order of picograms of BPA from planaria that live for a period of several days in media containing micromolar concentrations of the substance. During their time spent in this media, the planaria behavior changes dramatically. Movements become slower and their reactions to stimuli are delayed. Experiments were conducted to test the planarian's ability to regenerate during their exposure to BPA. The regeneration process involved cell proliferation for blastema formation and morphallaxis for symmetry and proportion. This allows the planaria to regenerate a tail from a head and a head from a tail. However, this regenerative ability is significantly impaired when BPA is present in the planaria's medium.

P1-151 MOORE, AJ; The George Washington University; *djmoore@gwmail.gwu.edu*

The evolution of somitogenetic variation in birds

Variation in vertebral number and regionalization is an important component of *bauplan* diversity in vertebrates, but drivers and constraints on the evolution of this variation are poorly understood. Previous studies have suggested that, with the exception of some snakes, fishes, and salamanders, vertebrates do not exhibit *pleomerism* — the phenomenon whereby segmentation and body size are positively correlated. While it is often remarked that birds exhibit considerable variation in vertebral count, it has also been argued that birds, like mammals, lack pleomerism because of their highly regionalized and functionally constrained axial skeletons. Here, I present results from an ongoing survey of avian axial regionalization, currently comprising data from 957 skeletons for 516 species, to which I apply phylogenetically-informed Bayesian comparative methods to test for pleomerism. Sampling densely within and across clades reveals that most clades exhibit little or no variation in pre-synsacral count, suggesting some degree of constraint on pre-synsacral somitogenesis within clades, while pleomerism is strongly expressed in the synsacrum regardless of clade-specific differences in ecology and pelvic morphology. Intraspecific variation is most common in the synsacral and caudal vertebrae. Grebes may be unique among birds in exhibiting cervical pleomerism, suggesting that constraints on somitogenesis may be relaxed in particularly long-necked taxa, though this remains to be rigorously tested in non-avian clades. These results demonstrate that pleomerism is an important aspect of body size evolution in birds and highlight the importance of dense taxon sampling for identifying relevant clade-specific variation in more general macroevolutionary trends.

80-1 MOORE, TY*; LARSON, JG; SANCHEZ PAREDES, CM; DAVIS RABOSKY, AR; University of Michigan, Universidad Peruana Cayetano Heredia; *taliaym@gmail.com*

3-D quantification and characterization of snake anti-predator behavior in the Peruvian Amazon

Coral snakes (genus *Micrurus*) have bright color patterns and distinctive behavioral displays that honestly signal their venomous bite to potential predators. While the coloration of coral snakes and their many harmless mimics has been well studied, the behavioral repertoires of these snakes, and other cryptically colored species within the same ecological community, have yet to be rigorously examined. Tropical snake behavior is challenging to study, due to changes in behavior in artificial settings, environmental hazards to electrical equipment, and difficulty capturing sufficient sample sizes with taxonomic breadth. By constructing wireless, waterproof, and portable data collection buckets with high definition video cameras, we captured the anti-predator behavior of snakes at the moment of collection from four sites in the Amazonian rainforests of Peru. We also constructed a pop-up kinematics lab to run a series of behavioral assays in semi-controlled conditions in the field. Over three month-long expeditions, we collected 1352 behavioral trials from 161 individuals from 51 species, including venomous models, harmless mimics, and non-mimicking snake species. We used qualitative analyses to characterize behavioral motifs and quantitative biomechanical analyses to characterize snake motions in three dimensional space. By placing these data in a phylogenetic context, we will test hypotheses regarding the evolution of behavioral mimicry, including quantifying the degree of mimetic convergence relative to sympatric cryptic species.

62-3 MOORE, ME*; HILL, CA; KESTER, KM; KINGSOLVER, JG; Univ. of North Carolina, Chapel Hill, Virginia Commonwealth Univ., Roanoke; *melmoore@live.unc.edu*

Lose/Lose Scenario: High Average and Fluctuating Temperatures Result in Parasitoid Death, but Fail to Save their Insect Hosts

Both mean and fluctuating temperatures can affect the growth, development and survival of ectotherms. These effects have been documented in many insects, including the tobacco hornworm (*Manduca sexta*), but how fluctuating temperatures alter host-parasitoid interactions is largely unexplored. Larvae of *M. sexta* are commonly used as hosts by the endoparasitoid wasp, *Cotesia congregata*; parasitized caterpillars inevitably die after wasp emergence. To investigate the thermal biology of this host/parasitoid system, we reared unparasitized (control) and parasitized *M. sexta* caterpillars at 3 average temperatures (25, 28 and 30°C) with 2 diurnally fluctuating temperature treatments (±0°C (constant) or ±10°C). Parasitoid survival was high at the lowest average temperature, and the effect of fluctuations was minimal. Wasp survival declined significantly as temperature increased, and mortality was exacerbated by diurnal fluctuations. The combination of the highest mean temperature and large fluctuations greatly reduced wasp survival, with no wasp emergence for most caterpillars. Despite complete wasp mortality, all parasitized caterpillars failed to successfully wander or pupate, and many grew to abnormally large sizes. Our results indicate that *C. congregata* are unable to successfully complete development at high average temperatures with large diurnal fluctuations. Since parasitism, successful or not, disrupts the normal development of *M. sexta*, parasitoid failure does not rescue the caterpillar from its inevitable death.

P2-220 MORAN, C/J*; GERRY, S/P; Fairfield Universty, Fairfield University; *cmoran@fairfield.edu*

Locomotor musculature tolerance of acute temperature change in two species of labrids

Acute temperature fluctuations are common in many nearshore marine habitats. Many small bodied reef fishes at temperate latitudes must cope with a wide range of thermal conditions as they do not migrate to follow optimal thermal regimes. Consequently, locomotor musculature must acclimate to a wide range of temperatures. Cunner is a small bodied labrid which occupy shallow reefs in the temperate Northwest Atlantic. This fish enters a state of hibernation in response to decreasing water temperatures. We aimed to demonstrate how this species copes with acute temperature changes to understand thermal tolerance of locomotor musculature. We hypothesized that cunner pectoral fin muscle would not differ in muscle kinetics when acclimated and tested at naturally occurring warm and cold temperatures. Following acclimation to warm (20°C) and cold (5°C) conditions, the pectoral fin abductor was tested in its acclimation and acute change temperatures. Cold and warm acclimated muscles did not differ in time to maximum twitch when subjected to an acute temperature change. When acclimated at the cold temperature and tested at the cold temperature muscles were slower to relax than the warm acclimated muscle tested at the cold temperature. Musculature acclimated at the cold temperature generally produced more power when at frequencies used during locomotion at the cold temperature. Cold acclimated muscle performed poorly when tested at frequencies commonly used during locomotion of warm acclimated fish. These experiments demonstrate that cues for hibernation in this species reduce overall muscle performance. Further work, with a large bodied congener will demonstrate the consequences of acute temperature changes on a large bodied temperate fish which migrates in response to decreasing temperature.

21-2 MORATH, J; Salt Lake Community College; *Justice.Morath@slcc.edu*

From Science Communication to a Conversation about Science.

The Community Writing Center (CWC) is an outreach program of Salt Lake Community College that helps the public in any writing that they are working on, regardless of educational background. Our motto is "Everyone Can Write." This comes from our philosophy that education and writing is a conversation between all parties involved; that the traditional deficiency model of education where the ‘learned' is a gatekeeper that bestows facts upon the ‘learner' fails in a number of ways. This is especially problematic when it comes to science communication. So we shifted the approach by extending our motto to "Everyone Can Think Critically." From that standpoint we then built two popular workshop series to facilitate conversations and dialogue around scientific literacy. The goals are to increase scientific and statistical literacy in the public while also increasing the ability for scientists to effectively communicate. The first is our Science Communication workshop series where local journalists, academics, and researchers collaborate on how best to present their work in an accurate and accessible way. The second is our Writing for Change workshop series for the general public where we work on various issues including how to write about and critically analyze statistics and factual claims they encounter in news and social media. The outcome has been hundreds of people collaborating on how to better understand and write on science and statistics- from people experiencing homelessness to retirees to high school students to Ph.Ds- and everyone in between. This presentation will be of benefit to researchers, educators, and science communicators. The presentation will include further discussion of our philosophy, the goals and content of our workshops, and how you might adapt this model to fit within your communities.

7-7 MOREHOUSE, NI*; BUSCHBECK, EK; ZUREK, DB; STECK, M; PORTER, ML; University of Cincinnati, University of Hawai'i at Mānoa; *nathan.morehouse@uc.edu*

The Molecular Basis of Spider Vision: New Opportunities, Familiar Players

Spiders are among the world's most species-rich animal lineages, and their visual systems are likewise highly diverse. These modular visual systems, comprised of four pairs of image-forming ‘camera' eyes, have taken on a huge variety of forms, exhibiting variation in eye size, eye placement, image resolution, field of view, and sensitivity to color, polarization, light levels, and motion cues. However, despite this conspicuous diversity, our understanding of the genetic underpinnings of these visual systems remains shallow. Leveraging publicly available transcriptomic and genetic data, we evaluated hypotheses about the origins, evolution and development of spider eyes. Our analyses highlight that there are many new things to discover from spider eyes, and yet these opportunities are set against a backdrop of deep homology with other arthropod lineages. For example, many (but not all) of the genes that appear important for early eye development in spiders are familiar players known from the developmental networks of other model systems (e.g., *Drosophila*). Similarly, our analyses of opsins and related phototransduction genes suggest that spider photoreceptors employ many of the same genes and molecular mechanisms known from other arthropods, with a hypothesized ancestral spider set of four visual and four non-visual opsins. This deep homology provides a number of useful footholds into new work on spider vision and the molecular basis of its extant variety. We discuss what some of the most productive first steps might be in studying the vision of these fascinating creatures.

77-6 MOREY, KC*; DANTZER, B; MCADAM, A; BOONSTRA, R; HUMPHRIES, MM; BOUTIN, S; NEWMAN, AEM; University of Guelph, Ontario, University of Michigan, Ann Arbor, University of Toronto Scarborough, Ontario, McGill University, Quebec, University of Alberta, Edmonton; *kmorey@uoguelph.ca*

Epigenetic transmission of maternal stress in a wild mammal

In laboratory model systems, the influence of maternal stress on the programming of an offspring's hypothalamic-pituitary-adrenal axis and related pyschopathology is well-described. However, the impact of the maternal effects of chronic physiological stress in natural populations is poorly understood due to challenges with studying transgenerational effects in wild mammals. The Kluane Red Squirrel Project, a 30-year interdisciplinary field study in the southwest Yukon (Canada), provides a novel opportunity to explore transgenerational effects in a precise, manipulatable, and ecologically-relevant way. Previous research conducted in this study system identified hormone-mediated maternal effects on offspring growth rate. Nonetheless, it is unknown if maternal effects observed in red squirrel offspring are also being mediated by neural changes within the endocrine system. Using red squirrels (*Tamiasciurus hudsonicus*), we are investigating the epigenetic regulation of glucocorticoid receptor expression in the hypothalamus and hippocampus. Specifically, we are quantifying mRNA expression and DNA methylation in offspring born to stressed and unstressed mothers to understand a potential genetic mechanism for the transmission of these maternal effects. This research represents an ecologically relevant exploration of wildlife epigenetics and opens the door to exploring the adaptive benefits of chronic physiological stress in the natural world.

12-3 MORINAGA, G*; BERGMANN, PJ; Clark University; *gmorinaga@clarku.edu*

Vertebral and axial kinematics of limb-reduced squamates

The vertebral column is a defining feature of vertebrates and has undergone various changes to support the functional demands faced by different species. One such change is the elongation of the body via addition of vertebrae accompanied by the loss of limbs. Among vertebrate lineages that have evolved such body shapes, squamates (snakes and lizards) are notable because this body shape has evolved at least 25 times, associated with fossoriality or inhabiting complex surface habitats like dense vegetation. And while both snakes and legless lizards have achieved elongation via addition of vertebrae, snakes have many more vertebrae (200-300) when compared to legless lizards (up to 110 vertebrae). These subtle differences in how elongation was achieved may have consequences on the kinematics of these animals. To test this, we compared vertebral and axial kinematics of the European glass lizard (*Ophisaurus apodus*), the Northern water snake (*Nerodia sipedon*), and the robustly-limbed fire skink (*Riopa fernandi*) as they travelled through narrow channels and fields of regularly spaced pegs. Preliminary findings suggest no differences in intervertebral joint angles regardless of the type of habitat treatment. Axial kinematics of the elongate *O. apodus* and *N. sipedon* were more similar than they are to those of *R. fernandi*. Thus, differences in how body elongation was achieved in the legless lizard and snake had no effect on the axial and vertebral kinematics of the species we tested.

P1-166 MOSO, E/M; ENZOR, L/A*; HANKINS, C; BARRON, M/G; EPA; *moso.elizabeth@epa.gov*

Combined effects of acidification and hypoxia on the estuarine ctenophore, Mnemiopsis leidyi

Estuaries are transitive zones which experience large fluctuations in environmental parameters (temperature, dissolved oxygen, pH, etc.). The interactive effects of reduced dissolved oxygen (DO) and elevated pCO_2 on estuarine organisms is not currently well understood. Ctenophores are an important factor in estuarine planktonic trophic pathways because they are voracious consumers of planktonic organisms. Ctenophores have shown a resistance to the negative effects of hypoxia, however, there is little information about their resistance to acidification and combined effects of hypoxia and acidification. This study determined acute sensitivity by measuring the survivability at two life stages of the ctenophore *Mnemiopsis leidyi*, larval (early cydippid) and adult (reproductive lobate). Over a 5-day test period ctenophores were exposed to four treatments: ambient, elevated pCO_2 (1300µatm, IPCC RCP 8.5 scenario), hypoxic (low dissolved oxygen, 2 mg/L), combined (elevated pCO_2 and hypoxic). Preliminary research suggests a sensitivity to elevated pCO_2 and combined treatments, and no effect in the hypoxic treatment.

111-5 MOSS, ND*; MASLAKOVA, SA; Oregon Institute of Marine Biology, University of Oregon; *nicole.moss@ucdenver.edu*

Regeneration Identifies Developmental Flexibility in the Pilidium Larva

Injury for long-lived planktonic larvae is likely, and therefore tissue reorganization and regeneration are expected. Like many other invertebrate larvae, the nemertean pilidium develops over several weeks in the plankton before it undergoes a catastrophic metamorphosis. In response to injury, the larval body is capable of regeneration at the expense of the developing juvenile structures. Comparing proliferation to developmental progress of the juvenile and larval structures highlights the relationship between regeneration and degeneration. Here we evaluate the contribution of putative stem cells and changes in the proliferation pattern in early stages of lappet regeneration. Lappet regeneration utilizes physiological maintenance associated with lappet growth. The process is driven by putative stem cell proliferation and re-patterned by existing structures in response to injury. Documenting regeneration in the pilidia has highlighted the relationship between regeneration and degeneration and the role of global signaling in response to injury.

34-3 MOUNTCASTLE, AM*; PAI, SN; HELBLING, EF; WOOD, RJ; Bates College, Harvard University, Harvard University; *amountca@bates.edu*

A wasp-inspired collapsible wing hinge dampens collision-induced body torques in a microrobot

Insect pollinators frequently experience inadvertent wing collisions with vegetation during foraging flights, which can cause cumulative and irreversible wing damage over time. Recent work has shown that some insects have evolved wing morphologies that help reduce damage associated with repeated wing collisions. Wasp wings feature a flexible resilin joint called a "costal break", located distally along the leading edge of the wing, which allows the wing tip to collapse reversibly when it hits an obstacle. A collapsible wing joint may benefit flight performance in yet another important way during collisions, by reducing extreme and unpredictable destabilizing torques on the body. We designed an artificial flexure hinge for the wing of an insect-scale microrobot, inspired by the costal break in wasp wings, and measured airframe body dynamics associated with collisions of the wing tip. We found that a bio-inspired collapsible wing hinge can dampen collision-induced body torques, but that the effect is correlated with wing stroke phase. Our results suggest that flexible wing tips may facilitate flight control in microrobots and insects alike.

1-3 MOUTON, JC*; WRIGHT, NA; TOBALSKE, BW; MARTIN, TE; MTCWRU, Univ. of Montana, Missoula, MT, Kenyon College, Gambier, OH, Univ. of Montana, Missoula, MT, USGS, MTCWRU, Univ. of Montana, Missoula, MT; *james.mouton@umontana.edu*

Stage-specific predation risk affects morphology, performance, and survival: an experimental test.

Predation is an important source of mortality and selection in wild populations across taxa. Where predation risk is predictable and heterogeneous, prey species are expected to evolve adaptive plasticity in traits that reduce the likelihood of being killed and eaten by predators. In young organisms, plastic responses to stage-specific predation risk are especially important because young tend to be particularly vulnerable and eventually life stage transitions can allow young to escape the risk all together. However, such plasticity may incur survival costs in later life stages from carry-over effects on phenotypic traits such as locomotor performance. Correlated shifts in behaviors, such as activity levels or microhabitat selection, may mitigate these costs in the wild, but strong tests in natural systems are lacking. We show that young songbirds exposed to high perceived nest predation risk leave the nest with less developed locomotor traits (e.g. shorter wings) and examine their flight performance, habitat selection, and survival after leaving the nest. Understanding how plastic responses to predation risk affect fitness later in life in natural systems promises to shed light on what limits the evolution of phenotypes.

P3-222 MUENZEN, K*; MONROY, J; FINSETH, F; Claremont Colleges; *kdmuenzen@yahoo.com*

Insights into the molecular evolution of the PEVK region of the giant muscle protein titin

Titin is a molecular spring in muscle responsible for muscle elasticity and sarcomere structure. The PEVK region of titin is composed of approximately 100 exons and is named for its high percentages of proline, glutamate, valine, and lysine amino acids. While known to play a role in passive force generation, little is known about how the variability of the PEVK contributes to muscle performance differences across vertebrates. Some studies have shown that titin isoforms with longer PEVK regions are stiffer than those with shorter regions resulting in higher passive myofibril and muscle stiffness. However, a more extensive description of the PEVK region could reveal evolutionary trends across vertebrates. In this study, we developed a novel annotation tool to characterize the PEVK region of titin across 40 mammalian species with a range of muscle physiologies. Results demonstrate three key findings about the evolution of titin. First, the number of PEVK exons varies widely across mammals with some having as few as 85 and others as many as 116. Second, a conserved, core of PEVK exons reside at the front end of the protein, followed by a hypervariable region. The hypervariable region is diverse at both the number of exons and sequence level. Finally, we performed positive selection analyses and identified 13 exons with evidence of recurrent, adaptive evolution at particular codons. These sites provide strong candidates for future work linking diversification of titin to changes in physiological performance.

31-6 MUKHERJEE, R.*; TRIMMER, B.A.; Tufts University; *ritwika.mukherjee@tufts.edu*

Fast movements in soft-bodied caterpillars

Fast movements in articulated animals (e.g., locust jumps), use levers, latches, or locks to pre-load a skeletal structure slowly and then release mechanical energy quickly. But soft animals lack such stiff elastic structures necessary for rapid movements. Some, like cuttlefish or squids, are highly pressurized and deform constant-volume tissues. However, caterpillars, despite being pressure-limited and non-hydrostatic, can perform rapid strikes, jumps, and ballistic rolls. *Manduca sexta* caterpillars strike defensively at noxious stimuli by whipping their head backwards. We characterized this behavior by using infra-red lasers to provide highly localized and repeatable heat stimuli. The latency between stimulation and beginning of strike suggests that strike movements are coordinated by central neural processing rather than local reflexes. In support of this, latency decreased with repeated stimulation and generalized to other locations consistent with centrally-mediated sensitization. Strikes could be evoked with two successive sub-threshold stimuli at different locations. When stimulated on both sides, strikes were generally towards the first side and rarely reversed direction. The tendency to strike decreased with increasing time intervals between the stimuli revealing a decay in sensitization with a time constant of 0.5 s (general only) to 1.1 s (local and general). High speed movement tracking revealed that strikes followed a broad general trajectory with course correction towards the end for targeting. During a strike the ipsilateral length of the segments decreased monotonically, but the contralateral length changed little initially then expanded suddenly suggesting a store-and-release mechanism. Neural control of these movements is being examined by recording the activity of identified muscles.

P1-88 MULAWA, EA*; KIRKWOOD, JS; WOLFE, LM; WOJDA, SJ; PRENNI, JE; FLORANT, GL; DONAHUE, SW; Colorado State University; *emulawa@colostate.edu*

Seasonal changes in endocannabinoid ligand concentrations between active and hibernating marmot (Marmota faviventris)

Hibernation is an ideal animal model to study diseases such as obesity and osteoporosis. Hibernators, marmots among them, are able to nearly double their body mass in fat stores and remain inactive for extended periods of time without exhibiting obesity or tissue atrophy. The endocannabinoid (EC) system is involved in modulating neural signaling, circadian rhythms, behavior, appetite, thermogenesis, as well as bone and energy metabolism. All of these systems are altered to maintain homeostasis during hibernation. This study aims to better understand the involvement of the EC system in the regulation of physiological processes during hibernation by quantifying EC and EC-like ligands for both active and hibernating marmots. We hypothesized that there would be significant changes in EC and EC-like ligand concentrations at the tissue level in marmots between active and hibernating states. Several EC and EC-like ligand concentrations were measured in brain, serum, brown adipose tissue, white adipose tissue, bone marrow, cortical bone and bone epiphyses using microflow chromatography coupled with tandem quadrupole mass spectrometry (LC-QQQ-MS). Significant findings included a 20-fold decrease in 2-arachidonoyl glycerol (2-AG) in cortical bone during hibernation, supporting our hypothesis and possibly suggest a peripherally controlled suppression in bone and energy metabolism.

P1-146 MUNIZ TIRADO, A*; MOOI, R; Albright College, California Academy of Sciences ; *adamaris.muniz001@albright.edu*

The hole truth: Evolutionary biology of novel features in keyhole sand dollars from the Pliocene of North America

Although there are about 250 living species of sand dollars (Clypeasteroida: Echinoidea), there are also more than 700 fossil forms. The richness of this record makes possible detailed exploration of evolutionary change. The sand dollar family Mellitidae, common on beaches today throughout the subtropical and tropical Americas, is also well-represented in Pliocene fossil deposits along the southeastern seaboard of the U.S. The family is characterized by holes that develop in the body skeleton (test). These holes, or lunules, pass completely through the test from top to bottom, and arose as adaptations to hydrodynamic forces in wave-swept environments. All mellitids have a lunule in each of the five rays (ambulacra), plus a single lunule in the posterior inter-ray (interambulacrum). In living members of the genus *Mellita*, the anteriormost ambulacral lunule is absent. Because mapping the occurrence of novel features in fossils can contribute to knowledge of speciation, we set out to: i) determine distribution and diversity of fossil *Mellita*; ii) determine when and where the anterior lunule was lost; iii) correlate systematics and evolutionary biology of *Mellita* with past environmental conditions to better understand how biodiversity varies with changes in factors contributing to modern biodiversity. With morphometrics, we aimed to determine if two Pliocene *Mellita*, *M. aclinensi*s and *M. caroliniana* comprise a single species, and explore the possibility that a thick, round-lunuled, undescribed form constituted a new species. Morphology, phylogenetics, biogeography and stratigraphy of all mellitid genera (*Mellita*, *Leodia*, *Encope*), were examined in a synthesis of the evolution of the family.

18-3 MUNOZ, MM*; HU, Y; ANDERSON, PSL; PATEK, SN; Virginia Tech, Boston College, University of Illinois, Urbana-Champaign, Duke University; *mmunoz5@vt.edu*

Strong mechanical relationships bias the tempo and mode of morphological evolution.

Morphological evolution proceeds unequally, leading some features to be highly diverse and others almost unchanged over millions of years. We capitalize on outstanding morphological, mechanical and phylogenetic datasets of several four-bar linkage systems in bony fishes and crustaceans to illustrate how mechanical relationships bias the tempo and mode of morphological evolution. Evolution is consistently faster in a subset of morphological traits exhibiting strong relationships with mechanical output. These systems vary in predatory behavior, body size, and locomotion, implying a generalizable phenomenon. Size-scaling differences in linkage geometry contribute to evolutionary rate disparity. Using the especially large wrasse dataset, we found that contingency and determinism underlie morphological evolution through many-to-one mapping. Whereas convergent mechanics evolved through different morphological pathways, shifts were nonetheless restricted to a subset of traits of high mechanical effect. Mechanical variation is predictably clustered around a few morphological traits, which could facilitate rapid ecological specialization through relatively small changes.

8-1 MUNRO, C*; SIEBERT , S; ZAPATA, F; DUNN, CW; Brown University, Providence RI, Brown University, Providence RI; University of California, Davis CA, Brown University, Providence RI; University of California, Los Angeles CA, Brown University, Providence RI; Yale University, New Haven CT; *catriona_munro@brown.edu*

Siphonophore Differential Gene Expression Patterns Analyzed within a Phylogenetic Context

Siphonophores, a group of colonial pelagic hydrozoans, represent an interesting case in the evolution of functional specialization. The functional units of the siphonophore colony are the zooids, which are homologous to solitary polyps and medusae in other hydrozoans. Siphonophore zooids are budded asexually from one or two growth zones, remain physiologically integrated and attached to a main stem, and become highly specialized for particular functions including feeding, reproduction, and locomotion. To understand how this functional specialization arises from the same genome within a colony, and how it has diverged across species, we are using a large RNA-seq dataset, generated from developing and mature zooids, to investigate differential gene expression patterns across zooids and species. The dataset consists of short read (50bp single-end) RNA-seq libraries from developing and mature zooids (5-7 zooid types, 2-3 replicates) in 7 species across the siphonophore phylogeny. Using the Agalma pipeline, we mapped the short read libraries to de novo transcriptomes (150bp paired end); additionally gene trees were generated for all homologous gene sequences. We analyse gene expression in a comparative phylogenetic context, and present analyses investigating the sets of genes that specify zooid identity, and gene expression patterns associated with zooid diversification events.

75-6 MUNTEANU, VD*; HEDRICK, BP; Clemson University, Harvard University; *vmuntea@g.clemson.edu*

Hit the Ground Running - How Locomotor Mode Affects Post-Cranial Morphology in Carnivorans

Tetrapod limbs, especially joints, are necessarily linked to locomotion and a large amount of work has been done studying the connection between locomotor mode and bony morphology. Mammals occupy a wide variety of locomotor modes and mammalian tarsal morphology in particular has been shown to be highly correlated with locomotion. Here we examine astragalar morphology in caniforms to see which specific structures of the astragalus are linked to changes in locomotor mode and whether the astragalus changes in consistent ways from one locomotor mode to the next. We examine astragalar morphology using 3D geometric morphometrics (3DGM) of 140 specimens across 53 species including 42% of the diversity of the non-pinniped Caniformia. Previous studies on locomotor morphology in Carnivora have focused only on ecologically-diverse clades within the order (e.g., mustelids); this is the first study to incorporate 3DGM at a finer taxonomic scale, seeking to elucidate morphological disparity and macroevolutionary trends within the order rather than across it. Preliminary results using principal components analysis show that there is significant morphological diversity between locomotor groups with arboreal caniforms and terrestrial/cursorial caniforms, creating a spectrum of astragalar shape - arboreal taxa tended to have shallower trochleae and more articular surface on the astragalar head when compared to terrestrial or cursorial taxa. Future work will incorporate phylogenetic comparative methods to evaluate whether ecology, phylogeny, or a combination of the two are responsible for discriminating groups. These results also contribute to a larger body of work demonstrating correlations between ecology and morphology and have the potential to help distinguish locomotor modes in fossil caniforms.

P2-213 MURPHY, CT*; CASPERS, PB; LAPSERITIS, JL; MARTIN , WN; Naval Undersea Warfare Center Division Newport; *christin.murphy@navy.mil*

Laser Doppler vibrometry and high speed videography for measurement of seal whisker vibrations in two planes of motion

Seal whiskers (vibrissae) vibrate distinctly when moved through the water. Variations in this vibrational signal may convey information about the flow features in the environment to enable these animals to accomplish their impressive hydrodynamic sensing and tracking behaviors. In order to better understand the signal input to the seal's sensory system, laser Doppler vibrometry (LDV) and high speed videography were utilized to measure the vibrations of excised harbor seal whiskers from stranding necropsy procedures. Testing was conducted in a research water tunnel across the range of biologically relevant swim speeds for this species (0.5-2.5 m/s) and at two angles of attack (0 and 90 degrees). LDV was used to capture single-point recordings of motion in the cross-stream direction, while high speed video tracking provided multi-point frequency measurements and imaging of whole-whisker motion in the streamwise direction. Across both methods, the measured vibration frequencies were within the known detectable vibrotactile range of the animal. When the two methods are compared, differences in the dominant vibration frequencies were observed. Coarse analysis of vibration modes from high speed video tracking was developed and supplemented with visualization of vibration modes through solid modeling based on geometries from CT scanning. The combination of these methods provides a more comprehensive insight into the seal vibrotactile system.

P1-249 MURPHY, PR*; WOLFE, LG; BURKART, EC; ROARK, AM; Furman University; *parker.murphy@furman.edu*

Do Algal Symbionts Communicate With Their Anemone Hosts Using Phytoestrogens?

Cnidarians are evolutionarily ancient metazoans, many of which form symbioses with intracellular, photosynthetic algae. It is assumed that this symbiosis primarily confers metabolic benefits to the host, with the organic products of algal photosynthesis donated to the anemone in return for inorganic nutrients. However, symbionts likely modulate host performance in other ways. For example, we recently demonstrated that symbiotic anemones (harboring symbionts) developed larger gonads than aposymbiotic anemones (lacking symbionts). We propose that symbiotic algae produce compounds that modulate the development and reproduction of their cnidarian hosts by acting on nuclear receptors. Like higher plants, free-living algae and cyanobacteria produce compounds including alkaloids, saponins, and flavonoids, many of which bind to nuclear receptors (NRs). Thus, it is likely that compounds from symbiotic algae affect host development and reproduction via such NR-mediated signaling pathways. These pathways presumably evolved early among metazoans. For example, steroids, which bind to NRs in more advanced metazoans, are found in, metabolized by, secreted from, and bioactive in cnidarians. The goal of this particular project was to screen compounds produced by algal symbionts (*Symbiodinium spp.*) for nuclear receptor (NR) agonism and/or antagonism using a competitive estrogen receptor (ER) binding assay. We also began to explore the mechanisms by which estrogenic compounds may function in cnidarians (specifically *Exaiptasia pallida*). Our results will be discussed in the context of interspecific cell signaling pathways.

P1-203 MUSAITIF, D; JOST, JA*; Bradley University; *jjost@bradley.edu*

Investigating the physiological effects of chronic cold exposure in the invasive zebra mussel

For sessile invertebrates, temperature fluctuations are unavoidable and often deleterious, causing reduced performance or survival. While there are many studies on heat stress in invertebrates, less is known about the effects of cold, especially on a cellular level. The invasive zebra mussel can serve as a model species for investigating the physiological response to long-term cold temperatures. A previous experiment showed phosphorylated AMP-activated protein kinase (pAMPK) levels increased with acute cold exposure. Given that pAMPK levels indicate metabolic stress and energy imbalances, data suggest mussels have increased energy demands in cold water, which seems unexpected for an ectotherm. One explanation is the process of seasonal acclimation is energetically taxing. Alternatively, cold exposure may cause cellular damage, increasing the energy needed for maintenance or repair. To investigate this response, mussels were either acclimated to 10° C for two weeks and held at 10° C for an additional four weeks or maintained at 26° C for six weeks. Mussel mortality, shell and soft tissue growth, hemolymph concentration, total antioxidant capacity, and the levels of heat shock protein 70 (HSP70), HSP22, total AMPK, and pAMPK were measured. Results show that total antioxidant capacity, hemolymph concentration, and shell growth did not vary between treatments. However, mussels in the 10° C treatment gained tissue mass while those at 26° C lost tissue. pAMPK, total AMPK, and HSP22 levels were significantly elevated in mussels held at 10° C, but the same was not seen for HSP70 levels. Overall, data do not suggest that 10° C is leading to substantial cellular damage, but rather these increased energy demands may be associated with the cellular changes associated with seasonal acclimation.

69-1 MYERS, BM*; CLARK, CJ; BURNS, KJ; MYERS, Brian; San Diego State University, University of California, Riverside; *bmyers@mail.sdsu.edu*

Behavior and Morphology Indicate an Allen's (Selasphorus sasin) x Rufous (Selasphorus rufus) Hummingbird Hybrid Zone Centered in Southern Oregon

Hybrid zones have received significant attention in biology, but few studies have investigated how behavioral traits vary across these regions of interaction. In a hybrid zone in southern Oregon and northern California between the Allen's (*Selasphorus sasin*) and Rufous (*Selasphorus rufus*) Hummingbirds, we found that hybrids vary in morphology and behavior. We describe the hybrid zone by characterizing variation in phenotype across the area of contact and study a novel courtship behavior in Allen's Hummingbird, the pendulum display. The courtship displays of both species involve a male hummingbird performing a J-shaped dive, during which the male produces a species-specific sound with his tail feathers. These displays can be broken into distinct elements, and some dive elements are analogous to those in the pendulum display. Hybrids perform courtship displays that incorporate different elements of the displays of parental species. Our data suggest the center of the hybrid zone spans from Bandon, Oregon, to Port Orford, Oregon, and spans several miles inland and north into the range of Rufous Hummingbird (as far north as Florence, Oregon), and south into the range of Allen's Hummingbird (as far south as Arcata, CA). Additionally, we find the breaks across the hybrid zone (pure Allen's to Allen's-like hybrid range, Allen's-like hybrid to the center, center to Rufous-like, Rufous-like to pure Rufous) correlate with variation in temperature and rainfall data, consistent with previous findings that suggest Rufous Hummingbird is dependent on habitat with cool forests with high rainfall. Few studies have incorporated analysis of the variation of behavior across an area of contact. By doing so, we add an additional, understudied layer of biology to the study of hybrid interactions.

112-5 MYERS, CE*; BERGMANN, KD; SUN, C-Y; TAMRE, E; MARCUS, MA; BOEKELHEIDE, N; KNOLL, AH; GILBERT, PUPA; University of New Mexico, Massachusetts Institute of Technology, University of Wisconsin-Madison, Harvard University, Advanced Light Source, Lawrence Berkeley National Laboratory, Colby College, University of Wisconsin-Madison; *cemyers@unm.edu*

Exceptional preservation of glycine-rich proteins and ultrastructure in Cretaceous bivalves

PhotoEmission Electron spectroMicroscopy (PEEM) was used to observe exceptional preservation of organic matrix components and shell ultrastructure in 66Ma bivalve shell. PEEM is a novel method to detect, in situ, preservation quality, and provides a non−invasive, non− destructive, and spatially explicit map of prismatic and nacre table ultrastructure, organics, minerals and their orientations. This technique was used to compare Cretaceous and modern bivalves in the genus *Pinna*; results demonstrate that 66Ma shells: (1) preserve original aragonite and calcite crystals in nacre and prismatic layers, respectively, (2) maintain original nacre tablet and prism ultrastructure and crystal orientations, and (3) preserve interprismatic organic proteins. Interprismatic proteins are glycine-−rich and preserved with intact peptide bonds. In both modern and Cretaceous *Pinna* shells, glycine is a major component of the interprismatic proteins, due to its importance for protein folding and mechanical flexibility. However, as the smallest amino acid, glycine is also the first to break down during diagenesis. Preservation of glycine chains in 66Ma shells supports the exceptional quality of protein preservation documented here. Notably, this quality of preservation may not be uncommon amongst fossil shells with nacre, because shell minerals entrap and protect organic compounds. Thus, PEEM analysis provides a new understanding the taphonomic processes in shell and molecular fossils, including the effects of molluscan diagenesis, physiology, biomineralization, and evolution on fossil preservation.

141-2 MYRKA, AM; WELCH JR., KC*; University of Toronto Scarborough; *kwelch@utsc.utoronto.ca*

Evidence of High Transport and Phosphorylation Capacity for Both Glucose and Fructose in the Ruby-throated Hummingbird (Archilochus colubris)

Hummingbirds are able to fuel hovering flight entirely with recently ingested glucose or fructose. Among vertebrates, several steps of sugar flux from circulation to skeletal muscle are potentially rate-limiting, including transport into muscle and subsequent phosphorylation. While capacities for glucose flux are substantial, capacities for fructose flux are comparatively low. The mechanisms underlying apparent high rates of glucose and fructose oxidation in hummingbird flight muscle remain unclear. We examined relative expression of facilitative sugar transporters (GLUTs) and enzymes of fructolysis in ruby-throated hummingbird (*Archilochus colubris*) tissues involved in energy homeostasis and flight, via qPCR and measured hexokinase activity in pectoralis in vitro. We hypothesized that expression of these genes was upregulated in hummingbird flight muscle compared to other vertebrates. We found that hummingbird pectoralis had among the highest expression levels of GLUT1 and GLUT5 among vertebrate muscles. In particular, GLUT5 expression in pectoralis was similar to that of intestine. We demonstrated minimal relative densities of fructolytic enzymes in pectoralis, suggesting that the ketohexokinase pathway does not rapidly metabolize fructose in these muscles. Instead, we found that the capacity for phosphorylation of either glucose or fructose by hexokinase is very high in pectoralis in vitro. The contributions of individual hexokinase isoforms remain to be determined. Our results further characterize the strategies by which hummingbirds, and perhaps other nectarivores, accomplish rapid sugar flux. High transport and sugar phosphorylation capacities appear to exist in flight muscle, though the enzymatic pathways that catalyze the phosphorylation of sugar in muscle remain uncertain.

P1-235 NABILI, P*; THORSEN, LS; MCDONALD, JM; SHINGLETON, AW; Lake Forest College, Lake Forest, IL; *nabilip@mx.lakeforest.edu*

Sex-specific plasticity and the nutritional geometry of insulin-signaling gene expression in Drosophila melanogaster

Sexual-size dimorphism (SSD) is replete among animals, but while the selective pressures that drive the evolution of SSD have been well studied, the developmental mechanisms upon which these pressures act are poorly understood. Previous research shows that SSD in *Drosophila* reflects elevated levels of nutritional plasticity in females versus males, such that SSD increases with dietary intake and body size. Additional data indicate that these differences in nutritional plasticity reflect sex-specific differences in how female and male body size responds to levels of dietary proteins and carbohydrates: specifically, while body size responds to variation in protein level in both sexes, only female body size is sensitive to variation in carbohydrate level. Here we explore whether these differences in nutritional sensitivity at the morphological level are reflected by differences in how the insulin-signaling pathway responds to changes in carbohydrates and proteins in females versus males, using a nutritional geometry approach. Our data suggest that there are sex-specific differences in the expression of insulin-like peptides but not, detectably, in the expression of genes regulated by the insulin-signaling pathway. These data support the hypothesis that, in *Drosophila*, SSD is regulated by the sex-specific differences in the release of insulin-like peptides under different nutritional conditions.

48-1 NAKANISHI, N*; MARTINDALE, M/Q; Univ. of Arkansas, Univ. of Florida; *nnakanis@uark.edu*

Ancient neuropeptides are not necessary for life cycle transition in a sea anemone

Neuropeptides are evolutionarily ancient, short polypeptide hormones that are expressed in the nervous and neuroendocrine systems of animals. Shared across Bilateria (e.g. insects and worms) and its sister group Cnidaria (e.g. jellyfishes and corals) are the Wamide and RFamide families of neuropeptides that appear to mediate a range of biological processes from motor behavior, reproduction, and development. In particular, it has been proposed that Wamides ancestrally controlled life cycle transitions from a free-swimming larva into a benthic (juvenile) form, because Wamides are sufficient to initiate life cycle transitions across cnidarians and annelid bilaterians. However, evidence for the necessity of Wamide signaling for such transitions is limited. By using CRISPR-Cas9-mediated reverse genetics, here we show that deeply conserved neuropeptides are not required for metamorphosis in the sea anemone cnidarian *Nematostella vectensis*. Transcripts of the cnidarian Wamide and RFamide—referred to as GLWamide and Antho-RFamide, respectively—are expressed in ectodermal sensory cells of a free-swimming planula larva; in addition, GLWamide transcripts, but not Antho-RFamide transcripts, occur in a subset of endodermal cells in the planula. However, null mutant planulae for either GLWamide or Antho-RFamide transform normally into primary polyps with oral tentacles. These results demonstrate that GLWamide and Antho-RFamide neuropeptidergic input from the planula larval nervous system is dispensable for the transition from a planula larva into a polyp in sea anemones, lending little support to the hypothesis that the key ancestral function of neuropeptides was to regulate life cycle transitions.

127-7 NAKATA, N; ELLINGSON, RA; KRUG, PJ*; Cal State L.A., UCLA; *pkrug@calstatela.edu*

When Photosynthetic Animals and Crunchy Algae Coevolve: Host and Herbivore Traits Interactively Determine Lineage Diversification in Sea Slugs

Longstanding interest in the eco-evolutionary dynamics of insect-plant and host-parasite systems has yet to clarify how traits of either consumers or their obligate prey affect diversification rates. ‘Musical chairs' models of host shifts versus ‘escape and radiate' cycles of niche expansion have proven hard to test, and little work has examined coevolutionary dynamics in marine taxa. Sea slugs in clade Sacoglossa are host-specialized herbivores that repeatedly evolved photosynthetic abilities (kleptoplasty). We built a database of diet records for 420 species, and a molecular phylogeny for 282 ingroup taxa, to reconstruct their history of host use. Using comparative methods, we then assessed whether traits of slugs or algae (or particular host groups) were linked with increased diversification of slug lineages. Photosynthetic slugs had higher rates of host shifting and diversification, but the degree of host-association did not affect slug diversity. Slug lineages feeding on uncalcified algae diversified more, but host chemistry had no influence on consumer diversification. Ancestral reconstructions supported recurring, sequential transitions between four host groups: Halimedineae to Bryopsidineae to Cladophorales to Dascycladales/non-chlorophytes. Bryopsidineae feeding lowered diversification by 50% for non-photosynthetic slugs, but increased diversification by 50% for photosynthetic lineages, while Cladophorales feeders diversified at twice the rate of lineages on the ancestral host group. Shifts to more derived hosts occurred frequently but greatly decreased diversification. Transitions to uncalcified green algae in temperate zones thus opened new niches and spurred cladogenesis, especially for photosynthetic slugs, but transitions onto non-chlorophyte hosts yielded many evolutionary dead-ends.

124-5 NANGLU, K*; CARON, J.-B.; University of Toronto, Royal Ontario Museum; *karma.nanglu@mail.utoronto.ca*

New Burgess Shale polychaete reveals the origin of the annelid head

Annelida is one of the most speciose (~17,000 species) and ecologically successful phyla. Key to this success is their flexible body plan with metameric trunk segments and bipartite heads consisting of a prostomium bearing most sensory structures and a peristomium containing the mouth. The flexibility of this body plan has traditionally been problematic for reconstructing the evolutionary relationships within the Annelida. While recent phylogenetic analyses, combining molecular and morphological data, retrieve two major clades within the crown-group, many questions remain regarding the early evolution of the annelid bodyplan itself, including the origin of the head, in large part due to the paucity of unequivocal annelid body fossils near their evolutionary origins. Here we describe a new Cambrian fossil polychaete based on abundant material from the 508 million year-old Burgess Shale Marble Canyon locality (British Columbia, Canada). Up to 2.8 cm in length, this new species possesses highly elongate chaetae, and its exceptionally preserved internal anatomy includes putative neural and vascular tissue. Most crucially, the head morphology includes a medial antenna (previously unknown from Cambrian forms) as well as a peristomium bearing uniramous parapodia and chaetae in addition to the mouth. A critical reappraisal of the Cambrian fossil annelids record lead us to propose a new hypothesis for the evolution of the modern annelid head condition which invokes developmental mechanisms found in extant taxa, namely the loss of juvenile parapodia during ontogeny in Magelona and peristomium+juvenile chaetiger fusion in Nereiidids. The medial antenna is likely autapomorphic and further suggests that a currently un-recognized morphological disparity may have existed amongst the early annelids.

P1-39 NANNINI, KT*; EERNISSE, DJ; California State University Fullerton; *kelsey311@csu.fullerton.edu*

DNA Barcoding of Diverse California Polyclads Has Global Implications for These Hard-To-Identify Flatworms.

Species identification is one of the most important uses of DNA barcoding, allowing researchers to be able to quickly identify a species without the often expensive and time-consuming process of consulting a specialist. Some animal groups are very difficult to identify and are currently lacking DNA barcodes for simple species identification. One of these groups are marine free-living polyclad flatworms. This group is found worldwide with over 1000 species classified into 27 families and almost none of these have DNA barcodes available. However, commonly employed primers to amplify mitochondrial COI for diverse animals unfortunately do not work for polyclads. Thus, we designed polyclad-specific primers and have successfully tested them with California polyclad species, well representing taxonomic diversity within the group. The resulting COI sequences will be made available internationally and will become one of the results of our study. Here, we are reporting the first-ever regional DNA barcode study of polyclads, and have supported it with the morphological identification of vouchered specimens, generously contributed by worm experts. We are also involved in testing non-lethal means to extract genomic DNA from polyclad mucus, which will enable researchers to positively identify living specimens for a variety of biological studies. Because polyclads have tremendous reproductive diversity, DNA barcoding could also be used to relate diverse plankton-collected polyclad larvae to the adults living on nearby shores, providing yet another means of identification.

P2-228 NAPOLI, JG*; TSAI, HP; TURNER, ML; MANAFZADEH, AR; GATESY, SM; Stony Brook University, Brown University, Brown University; *james.napoli@stonybrook.edu*

In- and Ex-Vivo Analysis of the Structure and Function of the Tendon of Sutton in Alligator mississippiensis

The evolutionary success of Archosauria makes it a compelling clade for the study of vertebrate evolution. Experimental study of living archosaur locomotion is critical to our understanding of the locomotor strategies of extinct archosaurs (including "rauisuchians", pterosaurs, and non-avian dinosaurs). In modern crocodylians and extinct non-avian archosaurs, *M. caudofemoralis longus* (CFL) is thought to play a critical role in hip function. The muscle originates from the tail and inserts onto both the femur and the lower leg, the latter insertion occurring *via* a long, thin tendon known as the tendon of Sutton. A similar anatomical system is found in limbed lepidosaurs. Although CFL's function as a femoral retractor has been well-studied in both archosaurs and lepidosaurs, the muscle's potential impact on more distal joints has been largely ignored. In this study, we used a combination of *in-* and *ex-vivo* approaches to study the function of the tendon of Sutton in the American alligator. XROMM, combined with dissection and CT imaging of cadaveric specimens, reveals that the tendon of Sutton possesses several insertions into the bones and soft tissues of the lower limb, is taut from late swing to early-to-mid stance, and deflects the external head of *M. gastrocnemius* and the femoral tendon of CFL itself. These data suggest that the tendon of Sutton allows these two muscles to work synergistically to increase torque about the knee and hip joints, improving the animal's ability to generate locomotor force, and have implications for anatomical and locomotor reconstruction in extinct taxa.

P1-234 NAVA ULTRERAS, B/M*; FARRAR, V; AUSTIN, S; LANG, A; MACMANES, M; CALISI, R/M; UC Davis , University of New Hampshire ; *bmnava@ucdavis.edu*

Got Milk? Gene expression of prolactin and its receptor in lactating rock doves

The hormone prolactin (PRL) plays a role in many physiological functions, though perhaps, it is best known for enabling lactation in mammals. PRL also regulates milk production in one of the few species of birds that produces crop milk, the rock dove (Columba livia). Circulating PRL concentrations increase over the course of incubation, peaking around the time chicks hatch and are first provisioned. However, less is known about 1) how reproductive tissues vary in receptor expression of this hormone over the course of reproduction and 2) whether this expression is mediated internally or by external environmental cues. To address this, we quantified gene expression of PRL and its receptor (PRL-R) in the pituitary, a main source of PRL production, and in the crop sac of both sexes during the parental care stage. Because both sexes produce milk and engage in contact-incubation and chick-rearing, we predicted males and females would expresses similar patterns of gene activity, and these patterns would be positively related to circulating PRL concentrations. In addition, we used egg removal and hatchling replacement manipulations during mid-incubation to test whether gene expression is internally or externally driven. In the pituitary, we found that PRL expression was similar in both sexes and mirrored patterns observed in hormone circulation. Upon replacing eggs with hatchlings during mid-incubation, PRL-R expression in the crop sac resembled peak expression observed when chicks hatch. This result suggests changes in crop sac PRL-R gene expression are externally driven, and milk production is influenced by the presence of offspring. Our findings offer a higher resolution and better understanding of the regulatory mechanisms driving rock dove PRL signal and signal sensitivity during lactation.

P1-170 NAVARRO, E*; GEORGE, SB; Washington State University, Georgia Southern University; *georges@georgiasouthern.edu*

DO Low Salinity Events affect Feeding in Echinoderm Larvae?

In the Salish Sea, Low Salinity Events (LSE) characterized by a decrease in salinity and an increase in temperature, are becoming common. They occur during the spring and summer months when Arctic ice melts, Fraser River discharge into the Salish Sea increases, and marine invertebrates including the sand dollar *Dendraster excentricus* and the sea star *Pisaster ochraceus* reproduce. During LSEs, temperatures can increase from 12° C to as high as 18° C and salinities can drop from 30 to 21ppt in a few hours around the San Juan Islands. Phytoplankton blooms are often associated with these events. Whether larvae of these species are able to capitalize on an abundance of phytoplankton during LSEs is unknown. This study looked at the effects of high temperatures (18-21° C) and low salinity (20 ppt) on larval feeding for both species. Sixteen, 26, 28, 39 and 41-day old *Pisaster* and 13, 15, and 17-day old *Dendraster* larvae were placed into one of three treatments: Control (C), low salinity (LS), or low salinity and high temperature (LSE) for 24 hours. They were then allowed to feed for 30 seconds, 5 minutes, or 10 minutes (depending on species and age) in bowls containing 1000 cells/ml of the alga *Isochrysis galbana* in either 30 or 20ppt. salinity. Particle capture increased with larval age and was generally higher for *Pisaster* than *Dendraster* larvae. Interestingly, *Pisaster* larvae fed at significantly higher rates after being exposed to a low salinity event for 24 hours than *Dendraster* larvae. This implies that*Pisaster* populations might be less affected by increases in low salinity events as their larvae might benefit from algal blooms associated with these events. These species-specific differences in response to LSEs could lead to shifts in community structure of intertidal habitats in the Salish Sea.

P1-121 NAVON, D.*; OLEARCYZK, N.; KARLSTROM, R.O.; ALBERTSON, R.C.; University of Massachusetts Amherst, Univ. of Massachusetts Amherst; *dina.navon.3@gmail.com*

Evaluating the molecular basis for diet-induced phenotypic plasticity in teleosts

Plasticity allows species to respond rapidly to environmental changes and may guide future evolution (via the flexible stem model). While it's thought that plasticity can evolve, little is known about its genetic underpinnings. Many teleost lineages have diverged along a benthopelagic axis encompassing coordinated shifts among behavior, morphology, and ecological niche. Importantly, some species exhibit significant plasticity along this axis while others do not. Previous work in our lab has identified candidate genes that underlie this phenomenon, including *ptch1*, a member of the Hedgehog (Hh) pathway, and *crocc2*. In order to test the hypothesis that these molecules mediate benthopelagic plasticity, we quantified rates of bone deposition in transgenic zebrafish in which Hh signaling and *crocc2* were directly manipulated, as well as in three species of cichlids with different *ptch1* and *crocc2* genotypes. Hh signaling was manipulated via heatshock while *crocc2* was knocked out using ENU mutagenesis. All fish were split into diet treatments mimicking benthic and pelagic feeding modes. Calcium-binding fluorochromes labeled bone at the beginning and end of each experiment. We focused on bones under high mechanical load during feeding, but also examined bones not engaged in foraging efforts as internal controls. In all, these data will serve to functionally test the relevance of candidate genes in establishing an ecologically-relevant plastic response, thus filling an important gap in the field.

P1-256 NAYLOR, ER*; HIGHAM, TE; University of California, Riverside; *emily.naylor@email.ucr.edu*

Toe pads and claws: Clinging performance in Phyllodactylus nocticolus, a leaf-toed gecko from southern California and the Baja Peninsula

Although the microstructural and mechanistic basis of gecko adhesion has been elucidated, further functional assessment across taxa is required to understand the evolutionary and ecological significance of this innovation. However, sampling within performance-related studies remains limited to roughly 20 species exhibiting the basal toe pad morphology and only two species with the derived leaf-like morphology. Moreover, the differential use of toe pads and claws in the wild has been formally documented in only a single species. We explored clinging ability in a native padded and clawed species, *Phyllodactylus nocticolus*, the Peninsular Leaf-toed gecko. Accounts of *P. nocticolus* climbing over and on undersides of various rocky substrate types point to the species' ability to manage a variety of surface conditions and potentially to an adept frictional adhesive system. We observed and captured individuals in the field, gathering general ecological (including substrate) and external morphological data and conducting two clinging performance assays using rough and smooth surfaces. First, we evaluated peak tension by allowing the gecko to freely place its forefeet onto a substrate and pulling the animal in parallel opposition to a force gauge. Second, we evaluated an angle of slippage during station holding using a rotatable platform (0 to 180°). Preliminary results indicate that this species has relatively low adhesive capacity compared to other geckos, both in terms of clinging force and station holding. Furthermore, clinging ability was greater on rougher surfaces, suggesting a heavier reliance on claw use and potential dissociation of the adhesive system with the substrate during clinging and climbing.

89-2 NAYLOR, M. F.*; GRINDSTAFF, J. L.; Oklahoma State University; *madeleine.naylor@okstate.edu*

Birds on Birth Control: Does Exposure to 17α -Ethinylestradiol Influence Corticosterone Levels in Male and Female Zebra Finches (Taeniopygia guttata)?

Many pharmaceuticals, upon entering the environment via wastewater treatment plants, are considered endocrine disrupting chemicals (EDCs). Through both direct and indirect effects, EDCs can impact the functioning of critical endocrine axes, including the hypothalamus-pituitary-gonadal (HPG) axis, and the hypothalamus-pituitary-adrenal (HPA) axis. The synthetic estrogen found in oral contraceptives, 17α -Ethinylestradiol (EE2), is considered an estrogenic EDC and is often detected in sewage effluent. Both aquatic and terrestrial animals can be exposed to EE2 in the environment with potential effects on stress physiology, namely the levels of the stress hormone corticosterone (CORT). We observed the effects of EE2 on baseline and stress-induced CORT levels in captive zebra finches (*Taeniopygia guttata*). We used three levels of EE2 exposure, 0 ng (control); 4 ng, which is a level found in streams near wastewater effluent sites; and 100 ng, which serves as a higher level not recorded in nature. Birds were exposed to their respective treatments every other day for three weeks before stress tests. We induced the stress response by fasting the birds for 4 hours and collected pre-and post-fasting blood samples. We found that baseline CORT responses were increased in 4 ng EE2 treated females in comparison to control and 100 ng EE2 treated females. EE2 treatment did not influence male baseline and stress-induced CORT levels. Female baseline CORT levels could be used to indicate environmental estrogenic EDC exposure, but more research is necessary to determine if increased CORT responses in females are observed in other species after EE2 exposure.

P2-52 NÉMETH, Z*; GRAVES, E; RAMENOFSKY, M; University of Debrecen, Univ. of California, Davis; *znemeth05@gmail.com*

Can Respiratory Rate Be a Useful Tool for Assessing the Adrenocortical Stress Response in the Field?

Modulation of respiratory physiology is part of the acute physiological response to stress. As respiratory rate has been shown to be repeatable within individuals over time, it has been increasingly used to characterize an individual's coping style. However, it remains unclear whether respiratory rate can be used to assess the activity of the hypothalamic-pituitary-adrenal axis in free-living animals. In our study, we addressed this question by investigating the link between changes in respiratory rate and plasma corticosterone levels during a capture-restraint protocol in the migratory and resident subspecies of the White-crowned Sparrow (*Zonotrichia leucophrys gambelii, Z.l. nuttalli*, respectively). Birds were sampled at 10, 30 and 60 minutes post-capture during different stages of their annual cycle. In general, plasma corticosterone level increased following capture, whereas respiratory rate decreased over the same period of captivity. Respiratory rate showed subspecies-specific relationship with plasma levels of corticosterone, exhibiting significant negative correlation in the resident subspecies and no correlation in the migratory subspecies. Our results suggest that respiratory rate may be useful as a noninvasive substitute to plasma corticosterone in a capture-restraint protocol in some species but the relationship has to be validated first.

P1-110 NEAL, SE*; DE JONG, DM; SEAVER, EC; Whitney Lab for Marine Biosciences, Whitney Lab for Marine Biosciences, University of Florida; *stephanie.neal123@gmail.com*

Functional investigation of a rhabdomeric opsin gene in Capitella teleta

There is a rich diversity of photoreceptors in annelids, making them an important group for studying the evolution of light detection. The opsins are a family of genes that encode light sensitive proteins. The annelid, *Capitella teleta*, possesses 9 distinct *opsin* genes. *Capitella* larvae are positively phototactic, although it is not known which *opsin* genes are responsible for this behavior. From initial expression analysis of three opsin genes, a single rhabdomeric opsin, *Opsin-119596*, is expressed in the photoreceptor cells of the eyes in *Capitella* larvae. This study directly investigates the function of *Opsin-119596* through knockout with CRISPR-Cas9, a technique that allows for targeted gene-specific knockout. Here, we established CRISPR-Cas9 technology for *Capitella*, and used three distinct techniques to assess gene knockout and function in larvae. First, PCR amplification and DNA sequencing was used to demonstrate efficient genomic DNA editing of the *Opsin-119596* locus. Second, using in situ hybridization, loss of the *Opsin-119596* transcript in the eye photoreceptor cells in *Capitella* was observed, presumably due to non-sense mediated decay. Finally, using a behavioral assay, there was a significant decrease in positive phototaxis relative to unmanipulated controls in *Capitella* larvae. This behavioral phenotype is similar to that observed when the entire larval eye is deleted. These results demonstrate the feasibility of gene editing using CRISPR-Cas9 in the annelid *C. teleta*, and establish a direct link between *Opsin-119596* and the positive phototactic behavior of *Capitella* larvae.

111-3 NEDVED, BT*; FRECKELTON, ML; HADFIELD, MG; Kewalo Marine Laboratory, University of Hawai'i at Mānoa; *nedved@hawaii.edu*

Bacterial induction of metamorphosis of Hydroides elegans (Polychaeta): A new twist in the tailocin tale

Phage-tail bacteriocins (tailocins) produced by the marine bacterium *Pseudoalteromonas luteoviolacea*, are encoded by a cassette of ten genes within the bacterial genome, and bacteria expressing these proteins rapidly induce larvae of the serpulid polychaete *Hydroides elegans* to metamorphose. Extensive research has demonstrated that six of these genes are required to generate an inductive cue by the HI1 strain of *P. luteoviolacea*. These genes (*macS, macT1, macT2, MacB, ORF2*, and *ORF3*) are also present in the genomes of several other strains of *P. luteoviolacea*, including the type strain (ATCC 3492). Further, we have used rtPCR to demonstrate that phage-tail bacteriocins are also expressed by the ATTC strain under normal culture conditions. However, monospecific biofilms of this strain do not induce metamorphosis of *H. elegans*. These data suggest that more than tailocins are necessary to induce metamorphosis. New experimental data indicate that outer membrane vesicles (OMVs) are also involved. Other species of inductive bacteria produce OMVs but not tailocins. We have used gradient ultracentrifugation to isolate and purify OMVs from *P. luteoviolacea* (strain HI) and found that they induce metamorphosis. It is now clear that the mechanism for induction of metamorphosis from *P. luteoviolacea* is not as straightforward as originally thought. It appears that OMVs form a second, concurrent mechanism of induction by HI1 strain.

P1-94 NEEL, LK*; MCBRAYER, LD; Arizona State University, Tempe , Georgia Southern University, Statesboro; *LKNeel@asu.edu*
Thermal physiology of invasive lizards changes seasonally
To understand how an introduced species spreads, biologists must study the physiology of invasive species. Adaptive plasticity of physiological traits, such as shifting in heat tolerance as the environment warms, likely helps a species invade novel environments. We studied the thermal physiology of the invasive lizard (*Leiocephalus carinatus*), which natively occupies rocky, open coastal habitats in the Bahamas, Cayman Islands, Cuba, and Honduras. This species was introduced to the southeastern United States in the 1940s and is now established in southern Florida. We quantified its thermal tolerance range and the thermal sensitivity of performance by sampling a population in West Palm Beach, FL during winter and spring. In spring, lizards tolerated higher body temperatures and reached greater maximal speeds but had narrower performance breadths. Our data suggest that the thermal physiology of the northern curly tail lizard can acclimate to climatic conditions. By assessing the ability of an invasive species to expand its range and acclimate to novel conditions, we can better understand how biological invasions occur.

90-8 NELSON, JA*; THORARENSEN, H; Holar University College/Towson University, Holar University College; *jnelson@towson.edu*
Using extant fishes to predict the future of freshwater fishes facing climate disruption
Climate projections predict temperature increases for many freshwaters and also flow regimes that are seasonally increased and more stochastic. Predicting the future of fishes that inhabit these waters will require knowing how they deal with changes of both temperature and flow. Presently, predictions of species' responses to climate change do not incorporate this knowledge. Fortunately, some species have already experienced the same changes predicted for climate disruption and we can learn from them. Impervious surface cover in cities causes greater surface run-off so that stream flows and temperatures are both greater and more stochastic. Urban fishes have been increasingly exposed to these changes over the past 200 years. The blacknose dace is found in some of the most urbanized streams, yet this fish is also abundant in nearby, rural streams. This sets up an intraspecific comparative experiment wherein one can test hypotheses concerning how the urban changes of temperature and flow have changed this species. Similarly, as the glaciers retreated from the island of Iceland over the past 10,000 years, they created a mosaic of freshwater habitats that vary substantially in both temperature and flow. A species indigenous to most of these waters is the Arctic charr, a fish known for its phenotypic plasticity which allows us to compare metabolism, performance and thermal tolerance of wild charr from waters of variant flow and temperature with cultured charr raised under a matrix of flow and temperature conditions in the laboratory for a single generation. Results to date have uncovered improved swimming performances and tolerance of thermal shock in urban dace populations, while wild charr from warm Icelandic streams have a temperature tolerance not inducible by a single generation of acclimation.

121-5 NEPTUNE, TS*; WATSON, CM; Midwestern State University; *tricianeptune@gmail.com*
Divergence of the physiological phenotype: variation in metabolic rate among Anolis oculatus ecootypes on Dominica
Extreme morphological divergence on islands is well documented, particularly among lizards in the genus *Anolis*. These lizards diversify into specific morphotypes on some islands, which results in speciation and niche differentiation. However, some islands such as Dominica have populations of Anoles that experience selective pressures resulting in different ecotypes, yet maintain a level of gene flow that precludes complete speciation. *Anolis oculatus* is the sole endemic anole species on the island of Dominica and it exhibits four morphologically-distinct ecotypes. These populations are easily distinguished based upon morphology and we set forth to determine if these morphological differences are mirrored by physiological differences in metabolic rate and its sensitivity to temperature. While Dominica is relatively small, it is thermally heterogenous, with cool mountainous regions and warm coastal regions and thermal vents. We measured oxygen consumption as a proxy for metabolic rate and determined its sensitivity to temperature in each of the four *Anolis oculatus* ecootypes at ecologically-relevant temperatures. We hypothesize that these differences in metabolism and temperature sensitivity is in part responsible for maintaining loose geographic segregation among ecootypes.

34-6 NEVELN, ID*; TIRUMALAI, A; SPONBERG, S; Georgia Institute of Technology; *ineveln2@gmail.com*
Just How Centralized is Cockroach Locomotor Control? Comparisons to Robotic and Computational Models.
High level tasks in biology, e.g. locomotion, are often achieved with distributed control of coupled subcomponents, e.g. muscles and limbs. The coupling of these subcomponents could range from weak and local, i.e. decentralized, to strong and global, i.e centralized. We developed a measure of centralization that compares information shared between control signals and both global and local outputs. We previously found that running cockroaches lie on the centralized side of this centralized/decentralized axis. To both validate the information measure of centralization and to contextualize the cockroach result with an intuitive system, we analyzed a computational model of coupled oscillators. Our centralization measure successfully reconstructs the shift from low to high coupling strengths. Intermediate values of coupling strengths which result in positive centralization correspond well to previous fits of this model to cockroach data indicating that this model can capture the centralization of the cockroach. Since mechanical coupling in a physical system might always result in a centralized system according to our measure, we analyzed a robotic model to contrast a decentralized architecture from the centralized cockroach. The robot control was designed to be reactive to local feedback, where coordination arises through mechanical coupling that can be altered by changing the robot's inertia. The robot is decentralized compared to the cockroach according to our measure and is maximally decentralized when mechanical coupling is decreased even though leg coordination persists. These results affirm that the cockroach does use a comparatively centralized control architecture and shows that our measure successfully assesses centralization using empirical observations.

89-3 NEWMAN, AEM*; STOTHART, MR; University of Guelph; *newman01@uoguelph.ca*

Does city life make a difference? Stress physiology and microbiome structure in urban grey squirrels.

Urban environments are amongst the fastest growing and most widely distributed ecosystems in the world, and organisms colonizing these environments are subject to a wide suite of novel stressors and selective pressures. While urban linked ecological changes have been well described, our understanding of the physiological mechanisms by which wildlife respond to these challenges is lacking. An organism's response to stressors is mediated by the hypothalamic-pituitary-adrenal (HPA) axis, a core component of the endocrine system and a key physiological mechanism connecting an organism to its environment. In addition, the HPA axis exists in an intimate bidirectional relationship with the microbiome. Using wild grey squirrels, we seek to understand the influence of the urban environment on stress physiology and the microbiome by characterizing patterns in glucocorticoid and microbiome profiles among urban and ex-urban environments. To explore the effect of urbanization on the HPA axis, we examined multiple measures of stress physiology differing in temporal resolution (chronic: hair cortisol; integrated: fecal glucocorticoid metabolites; acute: dexamethasone-adrenocorticotrophic hormone challenges). Subsequently, to probe the influence of HPA axis activity on microbiome structure and function, we performed a large-scale field experiment to manipulate glucocorticoids and assess corresponding changes in microbiome profiles. Unfurling the relationships between urbanization, stress physiology and microbiome structure in wildlife provide an opportunity to understand how wildlife cope with, adapt to, or even exploit novel environments.

89-5 NEYER, AA*; BACHMAN, GC; University of Nebraska-Lincoln; *neyeraa@gmail.com*

Glucocorticoid response of ornate box turtles to extreme temperature exposure.

Vertebrate animals respond to environmental stressors by secreting glucocorticoid hormones which help mobilize energy to support physiological processes and behaviors important for immediate survival. Ectotherms rely on environmental temperatures to regulate body temperature (T_b), and many escape extreme temperatures by moving to different microhabitats or constructing refuges. Therefore, ectotherms exposed to extreme temperatures may respond by secreting glucocorticoids in order to support thermoregulatory behaviors and changes in metabolic demands. As it can take time to move and construct safer refuges, it may be beneficial for glucocorticoids to increase in response to extreme temperatures even before T_b rises. In this study, we wanted to test whether exposure to extreme temperatures alone can initiate the glucocorticoid response. Ornate box turtles (*Terrapene ornata ornata*) with T_bs at 21°C were exposed for 1 hour to 21°C (control), 4°C (cold), or 38°C (hot). While this exposure time allowed for a change in T_b, this was not enough time for T_bs to reach experimental temperatures. We found that glucocorticoid concentrations were significantly higher in the cold exposed group compared to the hot exposed group. Also, we found that glucocorticoid concentration significantly increased as T_b departed from a preferred T_b (~28°C). These results indicate that glucocorticoid secretion may be dependent upon how far T_b departs from a preferred T_b rather than just exposure. However, as T_bs only rose slightly above preferred in our hot treatment, it is unclear whether this response also occurs at extreme hot temperatures. This presentation will conclude with a subsequent study testing the hypothesis that glucocorticoid concentration is correlated with how far T_b differs from preferred T_b at hot temperatures.

P1-140 NG, J*; HARRIS-WEAVER, C; BLOOM, D; LOVEJOY, N.R; BUSER, T.J; SUMMERS, A.P; KOLMANN, M.A; Univ. of Washington, W. Michigan Univ., Univ. of Toronto, Oregon State Univ.; *jnyk92@gmail.com*

Processes & mechanisms driving miniaturization in freshwater needlefishes

Marine to freshwater transitions play an important role in accounting for tropical freshwater fish biodiversity. Fishes which have historically invaded freshwater habitats from marine ones (marine-derived lineages or MDLs) may experience ecological opportunity, and are apt systems for examining how habitat transitions lead to ecomorphological diversification. We examined how such an ecological transition has affected the body-shape diversity of tropical needlefish and halfbeaks (Beloniformes). Body-shape and size correlate with many aspects of ecology and life history: foraging through locomotion and feeding morphology, reproduction by predicting offspring size and number, and more generally, larger fishes generally occupy higher trophic niches. Using micro-computed tomographic (µCT) scanning, geometric morphometrics, and phylogenetic comparative methods we examined body-shape evolution in 30 species of needlefishes from the Zenarchopteridae and Belonidae families. Using a multi-locus, published molecular phylogenetic tree, we examined patterns and tempo of evolution body-shape evolution in Asian and South American beloniform clades. We found that freshwater belonids have greater diversity in body shape than their marine relatives. The primary axis of body shape variation is elongation, driven by lengthening of either the rostral or trunk regions, and with miniaturization and ‘halfbeak' morphologies prevalent among freshwater species. While body shape diversity is greater in freshwater over marine needlefishes, access to new prey may also have influenced the evolution of freshwater taxa. In particular, we find that insect-feeding is also commensurate with many of the notable changes in body shape among freshwater beloniforms, moving the needlefish bauplan beyond ancestral piscivory.

118-2 NGUYEN, A*; BALABAN, JP; AZIZI, E; TALMADGE, RJ; LAPPIN, AK; California State Polytechnic Univ., Pomona, Univ. of California, Irvine; *allynnguyen@cpp.edu*

Fatigue Resistant Jaw Muscles Facilitate Long-lasting Courtship Behavior in the Southern Alligator Lizard (Elgaria multicarinata)

The Southern Alligator Lizard (*Elgaria multicarinata*) exhibits an unusual courtship behavior in which the male firmly grips the female's head in his jaws for several hours at a time. This behavior counters the conventional wisdom that the muscles of non-avian reptiles are fast to fatigue and incapable of sustaining high endurance behaviors. To quantify the contractile properties of the jaw adductors of *E. multicarinata*, we conducted *in situ* experiments in which the muscles of euthanized lizards were stimulated directly while bite force was simultaneously measured with a double-cantilever beam force transducer. Fatigue tests were performed by supramaximally and bilaterally stimulating the jaw-adductor muscles (internal adductor mandibulae complex) for several minutes with a series of tetanic trains (pulse duration = 0.2 ms, stimulation rate = 60 Hz, train duration = 150 ms, 1 train per 3 s). Our results show that a substantial residual force (approximately 15-20% of initial peak tetanic force) gradually develops during the first few minutes of the fatigue test, and this residual force persists after tetanic peak forces have declined to a fraction of the residual force (approximately 5 min into fatigue test). The observed residual force is consistent with the natural courtship behavior of these lizards, and it likely reflects physiological specialization related to the behavior. We propose that the presence of large populations of tonic fibers and/or a delayed Ca^{2+} reuptake mechanism may explain the unusual fatigue resistant properties of the jaw-adductor muscles.

P2-226 NGUYEN, KN*; VENKADESAN, M; Yale University; *khoi.nguyen@yale.edu*
Ensemble mechanics of myosin motors and material properties of the sarcomere
Muscles act as agonist-antagonist pairs at joints to move them and to also provide mechanical stiffness. The antagonist provides minimal resistance when stretched during motion to reduce energy consumption and mitigate the risk of tissue damage. This implies a fluid-like behavior, where the antagonist freely yields under external loads without building up stresses in the crossbridges. For providing stability or rejecting external pertubations, i.e. for mechanical stiffness, the agonist and antagonist behave like an elastic solid by resisting external loads and stressing the crossbridges. Here, we use an ensemble crossbridge model of the sarcomere to understand how muscle may accomplish these seemingly opposing demands of an elastic solid vs. viscous fluid. Actomyosin crossbridges elastically resist stretching on times shorter than the detachment timescale of myosin. Thus, the sarcomere resembles an elastic solid against fast perturbations (high frequencies). Over longer times (low frequencies), myosin motors cycle between bound/unbound states, thus releasing any stored elastic energy and the sarcomere yields in response to exteral loads. We show analytically that the mechanical response in the limit of infinite molecular bonds is a generalized linear viscoelastic model (Maxwell material) with multiple timescales over which stress relaxes at the crossbridges. The timescales emerge from the binding/unbinding rates, as well as the spread of crossbridge strains. Therefore, the sarcomere under stretching is not simply a linear spring and damper in series. Our analyses illustrate that slowing of the unbinding rate with load is central to the functional properties of the sarcomere, namely to yield freely against light loads and yet resist large loads.

P3-170 NICHOLAS, BP*; SUMMERS, AP; KOLMANN, MA; Oregon State University, University of Washington; *nicholbe@oregonstate.edu*
Diversification of Feeding Morphology in Marine and Freshwater Pufferfishes
Tetraodontid pufferfishes, with 187 species comprising 28 genera, have the smallest genomes of any vertebrate, can inflate themselves as defense against predators, have a bifurcated oral beak, and jaw closing muscles divided into as many 8 segments. They have also invaded freshwater on at least eight occasions across four continents. However, unlike other tropical marine-derived lineages (MDLs), pufferfishes have only invaded freshwater rather recently, relative to other marine invaders like stingrays, anchovies, and needlefishes. This study used micro-computed tomography to quantify feeding morphology traits in marine and freshwater tetraodontids and phylogenetic comparative methods to examine how morphological diversification in puffers has proceeded across the marine to freshwater transition. Freshwater pufferfishes do not have greater functional diversity in jaw morphology than saltwater pufferfishes. These methods also recovered widespread convergence in jaw function among many pufferfish dietary guilds. Omnivores, encrusted-prey specialists, and molluscivores exhibited the greatest convergence, while corallivores and crustacivores showed little to no convergence with other guilds across the first three PC axes. However, in at least one radiation of freshwater pufferfishes in Africa (*Chelodontops* spp.), we find evidence of novel selective regime acting on the feeding mechanics of these particular freshwater puffers. One of these *Chelodontops* species has actually re-invaded marine habitats, suggesting for these taxa, freshwater habitats have been catalysts for ecomorphological novelty. Tetraodontid feeding systems reveal themselves to be highly adaptable to myriad ecological niches and prey materials, whether in freshwater or marine habitats.

P3-36 NICKLES, KR*; HU, Y; MAJORIS, JE; BUSTON, PM; WEBB, JF; University of Rhode Island, Boston College, Boston University, Boston University; *krnickles@uri.edu*
Pre- and Post-Settlement Ontogeny of the Lateral Line System of a Caribbean Reef Goby, Elacatinus lori
Elacatinus lori is a shallow reef-dwelling goby from Belizean coral reefs that lives exclusively in tube sponges. It is being used as a model for the study of population connectivity and mechanisms of navigation during the pelagic larval phase. The lateral line system of gobies is characterized by a complex proliferation of superficial neuromasts arranged in numerous lines, which are quite difficult to interpret. However, the ability to rear *E. lori* from hatch through settlement provides insights not only into the ontogeny of sensory anatomy and putative sensory capabilities, but can show how a complex spatial pattern of sensory organs develops, and ultimately how it has evolved. The ontogeny of the lateral line system in larval (pre-settlement) and juvenile (post-settlement) *E. lori* was analyzed. Twenty-four individuals (3 mm TL - 62 mm SL) were imaged using 4-di-2-ASP (fluorescent mitochondrial stain) revealing superficial neuromasts distributions on the head, trunk, and tail. Images were supplemented with data from paraffin histology, SEM, and µCT, providing additional information on neuromast and cranial lateral line canal morphology. Superficial neuromast distribution maps for larvae, juveniles, and adults showed that superficial neuromasts are present at hatch, after which simple superficial neuromasts lines develop on the head (>30), on the body (arranged vertically on body segments) and on the tail (3); superficial neuromasts are proliferated at the time of settlement. Superficial neuromast lines in *E. lori* were compared to those in other *Elacatinus* species, the sister genus *Tigrigobius*, and other gobiids to better understand the evolution of complex gobiid lateral line phenotypes. Funded by NSF grant 1459224 to JFW and NSF 1459546 to PMB.

P3-260 NIEDERHAUSER, JM*; ANDERSON, RC; Florida Atlantic University; *jniederhause2015@fau.edu*
Habitat Variation in Relation to Bachman's Sparrow Nest Success and Nestling Condition
As humans change the environment around them, the need for reliable estimates of population growth are critical for all species, especially imperiled ones. Population models, however, often do not include accurate estimates of survival and reproduction because certain life stages or species are secretive or cryptic. Furthermore, many models do not include the multitude of environmental variables that affect adult and juvenile survival. Bachman's sparrows are Near Threatened songbirds that spend much of their lives hidden in the understory of pine flatwoods and prairies, and they prefer areas that are frequently burned by fire. The interactions between habitat, physiology, and behavior are poorly understood in this species, and the effects of these factors, and their interactions, on survival and reproduction have not been explored. In the first stage of this research, we found that some habitat characteristics affected nest success. Success differed between years and in relation to time since fire. However, vegetation characteristics did not vary in relation to time since fire and did not affect success or nestling condition. Nestlings were lighter in 2017 than 2016 possibly due to lower rainfall before and during the 2017 breeding season. Our results suggest that habitat affects nest success and nestling condition through other variables that relate to time since fire and rainfall, one potential being arthropod abundance. The next step will be to study the physiology and behavior of this species to determine how all three factors influence survival and reproduction.

S2-4 NISHIKAWA, K; Northern Arizona University;
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Muscle function from molecule to organism

There is a wide gap between our understanding of muscle contraction at the molecular level and our ability to predict in vivo muscle forces in animals during natural movements. We know that animal muscles can function as motors, springs, brakes, or struts, but we have little idea how muscle sarcomeres produce these different behaviors. During a work loop, a change in the phase of activation relative to the phase of length oscillations can convert a muscle from a motor into a spring. Current theories also fail to predict the increase in muscle force with stretch. They also fail to explain why a single stimulus added to a train of stimuli doubles the rate of force development. When stretch and doublet stimulation are combined in a work loop, muscle force doubles and work increases by 50% per cycle, yet we have no theory that explains why this occurs. Early studies circa 1970 suggested that all of the instantaneous elasticity of muscle sarcomeres resides in the cross bridges. In the 1990s, cross bridge models were developed that explained the increase in force during active stretch, but required assumptions now known to be unreasonable. Recent estimates suggest that cross bridges account for only ~12% of the energy stored by muscles during active stretch, and it is now apparent that the very small size of cross bridges and their cyclical behavior limits their ability to store energy. It was apparent much earlier that cross bridges were unable to account for the increase in force that persists after active stretching, leading to development of the sarcomere inhomogeneity theory. Most predictions of this theory fail, yet the theory persists. Based on these considerations, it is increasingly apparent that we need to consider structures other than cross bridges to understand the contributions of muscle to animal movement and motor control.

49-5 NOEL, A.*; HU, D.L.; Georgia Institute of Technology;
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How cats groom

The cat tongue is covered in sharp, rear-facing spines called papillae. These papillae are commonly thought to be used in grooming, although their precise function is a mystery. In this combined experimental and theoretical study, we examine the tongues of six cats: domestic cat, bobcat, snow leopard, cougar, tiger, and lion. Using micro-CT technology, we show that the papillae contain a hollow cavity at the tip, contrary to previous literature. These cavo papillae hold and distribute saliva deep into the fur layers. A constant cavity height across cat species corresponds to the height of compressed fur, suggesting papillae and fur evolved in parallel. We design and build a 3D-printed cat tongue mimic to demonstrate how anisotropic papillae can also facilitate easy hair removal post-groom. The unique micro-wicking mechanism in the cat papillae may inspire new fluid-saving techniques for cleaning hair, carpeting, and other porous media.

P3-265 NOLAN, PM*; VAN SKOIK, B; HART, T; The Citadel, University of Oxford; *paul.nolan@citadel.edu*

Non-invasive monitoring of penguin colony health.

Animals' external characteristics reveal details of their age, physiology, and/or body condition. Gentoo penguins (*Pygoscelis papua*) display a deep red beak spot, varying substantially between individuals, and shown experimentally to reflect concentration of carotenoid pigments. Carotenoid pigments may be used in mating displays or in the immune system, meaning that birds showing the deepest red are in the best condition. We sampled 50+ birds at each of 10 breeding colonies on the Antarctic peninsula. Using a color standard placed next to the bird in each photo, we standardized light levels of the photos before measuring hue, saturation, and brightness. We calculated colony-wide mean values along each of those parameters, and found substantial variation between the colonies. We compare those means with other publicly-available data to assess possible causes of the variation, considering prey availability, tourism visits, latitude, and ambient temperature changes as possible correlates. Importantly, we found no correlation between tourist visits and colony health. Our work will not only allow better management of human activities such as tourism and fishing in the Antarctic, it may help us predict future changes on the Antarctic peninsula.

P3-110 NOOR , J*; ALKOUK, A; MONZON, R; KROHMER, R; Saint Xavier University; *jaber.n03@mymail.sxu.edu*

Association of Spinophilin Expression with Dendritic Spine Formation in Hormone Treated Brains of the Red-Sided Garter Snake (Thamnophis sirtalis parietalis)

The Red-sided Garter snake *Thamnophis sirtalis parietalis* is an ideal animal for examining neuroendocrine factors associated with reproduction. Mating behavior in the Red-sided Garter snake, like many other hibernating animals, normally occurs during the spring season and this behavior has been shown to be correlated with the sex-steroid hormones estrogen and testosterone. It is believed that seasonal levels of sex hormones influence growth of neuronal dendritic spines, allowing for a greater number of synapses in the regions of the brain believed to be associated with the control of mating behaviors. Both sexes undergo aromatase dependent conversion of testosterone to the more potent hormone, estrogen. However, female Red-sided Garter Snakes have shown a greater neuronal response to estrogen, implicating a differential effect of hormones on dendritic spine formation in the associated brain regions. Spinophilin, an actin-binding scaffolding protein associated with dendritic spines in post-synaptic neurons, is used as a biochemical marker of dendritic spine formation. In this study, we perform western analysis to measure the concentration of spinophilin in four different brain regions (the olfactory bulb, pre-optic area, nucleus sphericus, and the hindbrain) from animals treated with testosterone or estrogen. Histological analysis of brains from hormone treated animals is also conducted to correlate morphological differences in dendritic spine formation with spinophilin levels.

BERN-1 NORRIS, D.O.; University of Colorado at Boulder; *david.norris@colorado.edu*

Five Decades of Environmental Comparative Endocrinology

All physiology and behavior is controlled or modified by hormones and other chemical bioregulators. Environmental endocrinologists study natural abiotic factors as well as biotic factors that operate through the neuroendocrine system to regulate development, growth, reproduction, and senescence. Investigative techniques used by environmental endocrinologists have shifted from organism level to gene action. Awareness of destructive effects of human activities on air and water quality led to the Clean Air and Clean Water acts and formation of the Environmental Protection Agency in the early 1970s. Things got better for the environment. However, biologists went back to our studies with the assumption that government was now safeguarding the environment. That changed in the mid-1990s with identification of widespread endocrine disruption linked to pharmaceuticals, pesticides, cosmetics, plastics and a host of industrial and agricultural chemicals. Research in the past 25 years has increasingly focused on anthropogenic chemicals that disrupt normal endocrine functions by mimicking or blocking bioregulator actions. These disrupting chemicals are found in every ecosystem on Earth at concentrations known to disrupt endocrine function in laboratory experiments. Some of these effects are reversible; others are not. The resulting endocrine disruption in vertebrate and invertebrate populations means that ecosystems being altered and that every biological investigation of natural populations is affected. We must communicate how biological systems operate, effects of endocrine disruption on these systems, implications for human health, and how best to diminish our destructive impacts on nature. And we need to communicate this to the general public who are now and will be in the future most profoundly affected.

51-2 NOTAR, JC*; JOHNSEN, S; Duke University; *julia.notar@duke.edu*

Do (Eyeless) Sea Urchins Have Color Vision?

Sea urchins appear to have spatial vision, despite lacking both eyes and eye spots. While investigations of their visual acuity and sensitivity have taken place, color vision in sea urchins is an unexplored possibility. Purple sea urchins, *Strongylocentrotus purpuratus*, express at least five opsins and therefore possess a potential physiological mechanism for color vision. Urchins are dominant, benthic grazers in a variety of marine habitats, and it is possible they may use color to identify food sources. Additionally, many species are known to aggregate with conspecifics or heterospecifics, indicating color could be used for intra- and interspecies recognition. Behavioral assays to determine urchins' reactions to stimuli of different color were conducted. Animals were placed in a round tank and allowed to choose between evenly spaced targets: multiple grey targets of various shades and one colored target. If urchins moved consistently toward or away from the colored target, and not a grey one of similar brightness, it indicated the ability to discriminate color. Results will be discussed.

39-3 NOVAK, RA*; HOWEY, CAF; The Pennsylvania State University, The University of Scranton; *ran7@psu.edu*

A Comparison of Macroinvertebrate Communities Among Vernal Pools with Varying Fire Histories

Prescribed fire is a technique used by land and forest managers to create more ecologically desirable vegetative habitat. Vernal pools, small bodies of water that fill in the winter or spring but dry up by the end of the summer, are often in the path of these prescribed fires. The purpose of this study was to investigate the impact of the changes in landscape brought about by prescribed fire on macroinvertebrate communities in vernal pool ecosystems. Water samples were collected throughout the year from 12 vernal pools with varying fire histories one and two years post-burn. Macroinvertebrates were counted and identified to family. We compared species richness and diversity among treatments and throughout years. Additionally, we measured pH, dissolved oxygen, and conductivity within each vernal pool, and canopy openness over each vernal pool. We tested for relationships among vernal pool characteristics and macroinvertebrate community composition. Our results will address if macroinvertebrates are affected by post-fire landscapes, and direct forest managers in their implementation of this landscape management technique.

P2-161 NOVARRO, AJ; University of Maryland, College Park; *Anovarro1@gmail.com*

Environmental and Evolutionary Drivers of Thermal Physiology in a Widespread Lungless Salamander

Understanding species responses to climate change has become a top priority for conservation biologists. Unfortunately, current models often treat species as a single entity, ignoring population-level variation. This is a major problem when managing widespread species, which often exhibit physiological variation across their geographic range. Lungless salamanders are especially vulnerable to climate change, due to their dispersal limitations and dependence on cool, moist conditions for survival. The eastern red-backed salamander (*Plethodon cinereus*) is a widely-distributed lungless salamander composed of six mtDNA clades, which differ in their climatic niches. Here, I compared the relative effects of environmental temperature and phylogenetic history on thermal traits in *P. cinereus*. Specifically, I measured critical thermal limits and thermal performance in thirteen populations representing three phylogenetic clades across the species' range. I found a strong phylogenetic signal in critical thermal limits, but not in thermal performance. Thermal performance was mostly driven by environmental temperatures at the population localities and conformed to the "hotter is better" hypothesis (i.e., salamanders from warm populations had higher thermal optima and performed better than salamanders from cool populations). My results shed light on the relative importance of environmental temperatures and evolutionary history on individual physiology. When integrated with population ecology, physiological traits can be used to better predict population viability in the face of climate change. Thus, understanding the physiology of widespread species provides a window into the past and a model for the future.

16-4 NUNEZ, CMV*; ADELMAN, JS; CARR, HA; JONES, MM; Iowa State University; *nunezcmv@iastate.edu*

Social Behavior and Ecology May Interact to Shape the Gut Microbiome in Feral Horses (Equus caballus)

The extirpation of their natural predators has necessitated the management of feral horse populations across the US. The contraception of females (mares) with porcine zona pellucida (PZP) is a popular option; however, effects to behavior can be substantial. For example, on Shackleford Banks, an island off the coast of North Carolina, treated mares have demonstrated decreased social fidelity, moving among historically stable groups (bands) more frequently than untreated mares. This behavior is consistent across the island, where differences in ecology dictate the degree of territoriality demonstrated by band stallions. We compared the gut microbial communities of mares that changed bands vs. those that did not while controlling for island region (a reliable proxy for stallion territoriality). We found that group changing behavior correlated with differences in gut microbial communities of mares living in territorial, but not non-territorial regions. The mechanism(s) behind these differences remain unclear, but we will present data on several candidates, including dietary differences, physiological effects of sub-fertility, and links between male aggression and female cortisol levels.

P2-114 NYUNG, JL*; EVERSON, CN; ROY, SW; San Francisco State University; *jeaniceljones@gmail.com*

A Bioinformatics Approach to Uncovering the Role of Alternative Splicing in Plants

Alternative splicing (AS) is a cellular process by which multiple messenger RNA (mRNA) species arise from the selective splicing of introns within a gene. RNA-sequencing (RNA-seq) data analysis of various places has yielded estimates of 61% of intron-containing genes undergoing AS. Despite this prevalence, little is known about AS's role in transcriptome complexity and genetic regulation in plants. We leveraged the availability of RNA-seq data from diverse plant species and life stages to compare profiles of AS across the plant kingdom. Using an iterative multi-step transcriptomics pipeline, we have performed an exhaustive genome-wide survey to systematically identify AS events in various plants and shed light on the role of AS in plants. This work revealed substantial variation in rate and form of AS across plant lineages, and insights into the functional pathways affected by AS in various lineages.

130-5 O'BRIEN, DM*; ALLEN, CE; VAN KLEECK, MJ; HONE, D; KNELL, R; KNAPP, A; CHRISTIANSEN, S; EMLEN, DJ; University of Montana, University of Hawaii, Manoa, Queen Mary University of London, Sentinel High School ; *devin.m.obrien@gmail.com*

The Evolution of Extreme Structures: Inferring Function from Pattern

Understanding how morphology scales with body size is one of the most pervasive topics in evolutionary biology. In the context of static scaling, the extreme products of sexual selection are of particular interest. Ornaments of choice and weapons of battle grow to drastic proportions, and typically scale steeply with body size when viewed across a population. This pattern is widespread, and tests of steep scaling are commonly used to infer a sexual selection function. However, the degree to which patterns of static scaling reflect weapon/ornament evolution and, by extension, the degree to which these patterns provide insight into biological function, remains unclear. Here, we compare a suite of extreme structures (14 signaling, 15 non-signaling) to more typically proportioned 'reference' structures within the same organism. We show that steep static scaling relationships are common when structures function as signals of overall quality, but not for comparably extreme structures that function in other contexts. We review the literature surrounding animal signals, discuss our results in the context of sexual selection, signal function, and morphological scaling, and argue that the function of sexually selected signal structures can indeed be inferred from patterns of static scaling.

111-1 O'BRYANT, SM; MARTINEZ-ACOSTA, VG*; Univ. of the Incarnate Word; *vgmartin@uiwtx.edu*

Cellular and Molecular Characterization of Head Regeneration in Lumbriculus variegatus.

Lumbriculus variegatus is a freshwater annelid that has robust regenerative capabilities. Previous work in our lab has demonstrated that proper head regeneration is a crucial step for downstream mechanisms that mediate functional recovery of behaviors within the original worm fragment. We describe cellular changes occurring at the head blastema and identify proteins that are changed in their expression within the regenerating head and in segments located just behind the head. Experiments removing thirty-segment fragments from either the anterior or posterior region of the worm, demonstrate that the head always regenerates on the anterior end of the fragment, regardless of which position along the body axis the fragment was removed (n=10). This data suggests that polarity of the injured fragment is maintained. However, when worms are amputated at varying positions along the anterior-posterior axis, asexual fission planes form more readily (n=17; 76.5%) in the anterior 1/3 region in comparison to injury within the posterior 2/3 region. Molecular expression in regenerating head segments was characterized using antibodies raised against Drosophila wingless protein and antigens isolated from regenerating blastemal tissue in planaria. The antibody raised against blastemal antigens (1D9-E11) demonstrated the most unique staining patterns in regenerating head and tail tissue with puncta found throughout each region and along the top of the ventral nerve cord. Immunoblots using the 1D9-E11 antibody identified the presence of 3 positive protein epitopes: one that is 126-129KDa, one that is 103-109KDa, and another that is 87KDa in size. Differential expression of the antigen was detected in regenerating head and tail tissues. Taken together these data demonstrate cellular and molecular events that are specific to head regeneration.

35-2 O'CONNOR, RS*; BRIGHAM, RM; MCKECHNIE, AE; University of Pretoria, Hatfield, South Africa, University of Regina, Saskatchewan, Canada; *oconn163@gmail.com*

Thermoregulatory Patterns in Free-Ranging Populations of Two Southern African Arid-Zone Nightjars

Endotherms expend large amounts of energy and water to maintain a preferred body temperature (T_b), but can potentially alleviate thermoregulatory costs by allowing T_b to deviate from normothermic levels. Many data on heterothermy at low air temperatures (T_a) exist for caprimulgids, whereas data on thermoregulation at high T_a are largely absent, despite the propensity for these birds to roost and nest in thermally exposed sites where operative temperatures can approach 60 °C. We investigated thermoregulatory patterns in free-ranging Rufous-cheeked Nightjars (*Caprimulgus rufigena*) and Freckled Nightjars (*Caprimulgus tristigma*) in the southern African arid zone. Individuals of both species showed a labile T_b fluctuating around a single modal T_b ($T_{b\text{-mod}}$). Average $T_{b\text{-mod}}$ was 39.7 °C for Rufous-cheeked Nightjars and 39.0 °C for Freckled Nightjars. In both species, diurnal T_b increased with increasing T_a. At $T_a \geq 38$ °C, Rufous-cheeked Nightjar mean T_b increased to 42 °C, equivalent to 2.3 °C above $T_{b\text{-mod}}$. Under similar conditions, Freckled Nightjar T_b was on average only 1.1 °C above $T_{b\text{-mod}}$, at a mean T_b of 40.0 °C. Freckled Nightjars are one of the most heterothermic caprimulgids, but our data suggest that during hot conditions this species maintains T_b within a narrow range above $T_{b\text{-mod}}$, possibly reflecting an evolutionary trade-off between decreased thermal sensitivity to lower T_b but increased thermal sensitivity to high T_b. Our results reveal how general thermoregulatory patterns at similar T_a can vary even among closely related species and raise important questions regarding the coadaptation between thermoregulation and thermosensitivity among highly heterothermic groups.

136-1 O'CONNOR, MP*; O'DONNELL, S; Drexel University; *oconnomp@drexel.edu*

Iterative signaling and biological system performance

Responses of hierarchically organized biological systems (e.g., insect colonies, nervous systems) to stimuli often depend on the recruitment of individual subunits (e.g., insects, neurons) to specified tasks. We developed a Markov chain based model of the rate and extent of recruitment of individuals to tasks that require iterative stimulation to activate individuals to a task. The model posits that activation depends on four biological parameters: the frequency of individual stimulations, the probability of 'forgetting' previous stimuli, the cumulative number of stimuli that must be accumulated before an individual is activated to a task, and the rate of deactivation once activated. Predicted patterns of activation agree with anecdotal data and predictions of earlier models. Further predictions include: 1) All four parameters strongly affect activation under some combinations of the other parameters. 2) Different patterns of activation (rapid, slow, most vs few individuals activated) can each be achieved via several, alternate combinations of parameters. 3) The 'size' of the system (number of individual units) does not affect the expected rate of activation, but does affect the stochastic variation around that expectation in individual simulations. 4) Short term dynamics of the system can include deterministic oscillations in the level of activation. Biological costs (e.g., time and energy costs) may constrain the parameters of iterative stimulation for a given system.

86-4 O'DONNELL, MK*; DEBAN, SM; University of South Florida; *mkodonnell@mail.usf.edu*

Scaling of Clinging Performance in Plethodontid Salamanders

Clinging and climbing ability can confer fitness advantages through ability to traverse obstacles, access food resources, and shelter from ground-dwelling predators or unfavorable climatic conditions. Many species of plethodontid salamanders have demonstrated obligate or facultative arboreality and scansoriality; in the absence of claws or specialized adhesive toe pads, attachment to smooth surfaces is attributable to either suction in web-footed species or the adhesive properties of mucus on ventral body surfaces. Plethodontid salamanders show significant variation between species in maximum clinging performance. The ratio of body mass to functional adhesive surface area is predicted to play a large role in determining clinging performance. If surface area scales isometrically with body mass, low performance in large-bodied species may result. Significantly higher clinging performance in large species despite low surface area to body mass ratio would suggest species-specific attachment specialization. We measured the functional adhesive surface area of attachment used during clinging on a smooth acrylic surface in semi-aquatic, terrestrial, troglodytic, and scansorial species of plethodontid salamanders. We also measured scaling of functional adhesive surface area within two species, *Plethodon metcalfi* and *Desmognathus quadramaculatus*, across a range of body sizes. Maintenance of high performance at high attachment angles in some large species is attributable to high surface area to body mass ratio achieved either behaviorally or morphologically. Within species, performance decreases with increasing body mass. Significant differences in scaling of clinging performance between *Desmognathus* and *Plethodon* suggest variation in the adhesive properties of the mucus coatings on the two species.

P2-195 O'REARDON, AB*; OLBERDING, JP; University of South Florida , University of California, Irvine; *aoreardon@mail.usf.edu*

Arboreal frogs don't let any angle slow them down

Jumping is essential for arboreal animals in behaviors such as capturing food and evading predators, but animals must jump from surfaces with different properties and orientations, like tree trunks, branches, leaves, or the ground. Different surfaces can impact the way that morphology and physiology interact with the environment to produce movement. We hypothesized that animals jumping from vertical surfaces would have lower performance compared with more horizontal surfaces because the changing orientation of gravity relative to the body would reduce the ability to effectively transmit force to the surface. We measured position, velocity, and acceleration from Cuban tree frogs jumping from surfaces at 45, 60, 75 and 90 degrees to test the prediction that jump performance would be greatest at 45 degrees and would decrease as the angle increased. We also measured jumps across a range of body masses to assess the impact of size on performance at different angles. Jump performance data was collected within a temperature controlled room from 29 frogs using a three-dimensional motion capture system in which a reflective infrared marker was used to track the frog through space. Contrary to our hypothesis, jump performance remained unchanged across all 4 angles and was unaffected by body mass. These results suggest that these arboreal frogs are well suited for these angles as they commonly experience them in nature. Future experiments measuring ground reaction forces may reveal the mechanism by which these animals overcome the challenge of the changing orientation of gravity relative to the body to maintain high jump performance.

63-4 OAKLEY, TH*; JUAREZ, BH; SPEISER, DI; OAKLEY, Todd; UC Santa Barbara, Iowa State, U of South Carolina; *oakley@lifesci.ucsb.edu*

Macroevolution of Ostracod Eyes and Body Size Along the Ecogeographical Gradient of Ocean Depth

Testing ecogeographical rules, which posit strong relationships between organismal phenotypes and habitat, can help us understand evolutionary mechanisms that generate biodiversity. Although not formally named an ecogeographical rule, environments at different ocean depths vary in predictable ways important to organisms living there. Our knowledge of these factors, coupled with our understanding of metabolism and visual ecology, predicts strong associations between organismal phenotypes and oceanic depth. A valuable group to study these associations is cylindroleberidid ostracods (Crustacea). We used comparative methods to ask how habitat depth is related to eye morphology and body size (carapace length) in cylindroleberidids because of previous phylogenetic analyses, and their enormous depth range. We collected and analyzed data for 128 species, including 37 that lack eyes. For each, we recorded habitat depth, body size, diameter of the largest ommatidium in the eye, eye size, and number of ommatidia per eye. We find no evidence for the general prediction that body size decreases with depth due to lower food availability. We also find that eye length and ommatidium diameter are not related to depth, counter to a prediction that species living at greater depths have larger eyes that gather light more efficiently. Defying simple explanation, we find strong evidence that ommatidia count decreases with depth in the photic zone, but we see the opposite trend in the dysphotic zone. Finally, we find as expected a significantly higher proportion of eyeless species with depth. Taken together, our results indicate that morphological changes along ecogeographical gradients do not follow simple relationships. Instead, exceptions to simple predictions of morphological changes sometimes depend on interactions between characters, phylogeographic history, and non-linear relationships between habitat gradients and characters.

P1-71 OAKLEY, TH*; MOTTA, CA; SAHA, R; LOCKER-CAMERON, TR; HENSLEY, NH; RIVERS, TJ; UCSB, Bates College, U Kansas; *oakley@lifesci.ucsb.edu*

Waterborne Autonomous Low Light Electrostereovideography (WALL-E) to Quantify Luminous Courtship Signals of Ostracods

Dozens of cypridinid ostracod species produce different luminous courtship displays throughout the Caribbean. Quantifying these courtship patterns quickly and precisely remains challenging. We designed submersible, low-light video cameras, deployed in tandem that record to an on board Digital Video Recorder (DVR). We call this dual camera system WALL-E (Waterborne Autonomous Low Light Electrostereovideography) because of its unintentional, yet uncanny resemblance to the main character of the Pixar movie. We successfully deployed WALL-E in the field and recorded usable video for multiple species' signals. We are now developing semi-automated computer vision software to quantify courtship signals from lab and natural habitats. By quickly quantifying courtship signals, we will be able to compare newly discovered signals to known ones, and produce models that allow simulated displays for behavioral experiments.

122-1 ODONNELL, DJ*; HRISTOV, NI; CHADWELL, BA; ASHLEY-ROSS, MA; Wake Forest University, Center for Design Innovation, Ohio University Heritage College of Osteopathic Medicine; *odondj15@wfu.edu*

The Mechanics of Righting Behavior in Theraphosid Spiders

The ability for an organism to right itself (correcting the orientation of its body when overturned) in its environment is crucial to survival. Righting behavior can vary widely among taxa, and is largely based on body morphology. Tarantula righting behavior is not only needed in critical situations (falling and landing upside down), but is necessary after molting, when the spider/organism must intentionally turn itself upside down in order to shed the old cuticle. In order to describe and analyze the mechanics of this behavior, 33 external markers were painted on leg joints and abdomen. After being placed on their backs, the tarantulas were filmed simultaneously with four spatially calibrated, and time-synchronized, high speed video cameras. Righting behavior was digitized in Matlab to create a 3D model for visualization and analysis.We observed a stereotypical sequence where the fourth pair of legs is used to lever the cephalothorax off of the substrate, assisted by the third pair of legs. The first and second pairs of legs are typically used to make contact with the substrate via the scopular hairs. Once attachment to the substrate is made by one foot, the tarantula appears to pull itself over with the first and second legs, and push with the contralateral third and fourth legs. The efficiency with which tarantulas conduct this stereotypical behavior displays how such morphologically complex organisms can have an extraordinary amount of control when moving their bodies.

P2-104 OHDERA, AH*; AMES, CL; DIKOW, RB; HERNANDEZ, AM; BUSBY, B; LA, S; PIRRO, S; MEDINA, M; COLLINS, AG; RYAN, JF; Pennsylvania State University, National Museum of Natural History, Smithsonian Institution, Data Science Lab, Smithsonian Institution, Whitney Laboratory for Marine Bioscience, University of Florida, National Center for Biotechnology Information, Simon Fraser University, Iridian Genomes, Inc.; *auo140@psu.edu*

Box, stalked and upside-down? Draft genomes from diverse jellyfish (Cnidaria, Acraspeda) lineages: Alatina alata (Cubozoa), Calvadosia cruxmelitensis (Staurozoa), and Cassiopea xamachana (Scyphozoa)

The major cnidarian lineages differ dramatically in their body plan and life history strategy. Anthozoans remain sessile as adults while medusozoans generally have a pelagic stage in their life cycle: the medusa. It is currently not known how these fascinating transitions occurred during evolution. In order to understand the genomic changes underlying the diversity within Cnidaria, we sequenced, assembled, and annotated genomes from three major jellyfish groups: Cubozoa, Staurozoa, and Scyphozoa. Here we present analyses of the genomes of Alatina alata, Calvadosia cruxmelitensis, and Cassiopea xamachana. As part of these analyses, we have identified gene losses in various cnidarian groups, as well as conserved gene synteny across Cnidaria. These resources and preliminary analyses provide insight and critical resources needed to understand the evolutionary processes that have driven the extraordinary evolutionary innovations that have occurred in Medusozoa.

P3-125 OHLINGER, BD*; KLINGER, TS; DAVIS, GT; HRANITZ, JM; Bloomsburg University of Pennsylvania; *Bdo73702@huskies.bloomu.edu*

Innate Flower Color Choice and Flower Constancy in a Solitary Bee and a Social Bee

Individual bees often specialize on one flower, flower constancy, while bypassing equally rewarding flowers. To better understand flower constancy behavior, we compared flower color choices by honey bee (*Apis mellifera*) and *Megachile rotundata* foragers in North Central Pennsylvania. Our goal was to determine (1) if innate flower color choice differs between a solitary bee and the eusocial honey bee, (2) if initial flower color choice is impacted by flower frequency, and (3) if flower constancy corresponds to their innate flower color choice. We observed naïve and experienced bees as they visited 6 x 6 Cartesian grids with frequencies of blue (B) and yellow (Y) artificial flowers of 50 B/ 50 Y, 75 B/ 25 Y and 25 B/ 75 Y. Initial flower color choice by individual naïve bees was used to determine innate flower color choice, while the first 10 visits to artificial flowers were used as a measure of flower constancy. We observed 103 initial visits from naïve *A. mellifera* foragers, and 578 visits from 72 experienced *A. mellifera* foragers. Both experienced and naïve foragers preferred blue flowers, with blue preference being more pronounced in experienced foragers than naïve foragers. Blue flowers were visited at a higher proportion than their frequency on the Cartesian grids in all three treatments, with increased visitation to yellow flowers in the 25 B / 75 Y treatment. *M. rotundata* also preferred blue artificial flowers. Our study corroborates the preference for blue flowers by naïve and experienced bees, for both *A. mellifera* and *M. rotundata* reported in earlier studies. Our results also indicate that individual honeybees adapt foraging behavior to changes in flower color frequency, consistent with optimal foraging strategy.

P1-289 OHRENBERGER, J/A*; GIDMARK, N/J; FARINA, S/C; University of New Hampshire, Knox College, Harvard University; *jo1016@wildcats.unh.edu*

To Bend, or Not to Bend? Hinged Teeth in the Goosefish Lophius americanus Have Multiple Functions and Two Distinct Lever Systems

Lingually hinged teeth are useful for sit-and-wait ambush predators, such as the goosefish *Lophius americanus*. They bend inward to allow prey to be easily pulled into the mouth, but their limited forward bending prevents prey from escaping. In this study, we use illustrations, photographs, and tooth measurements to document the hinging mechanism in Lophius americanus. The hinged teeth of Lophius are not ankylosed to the jaw, and the base of the tooth sits on a semicircular tooth pedestal protruding from the jaw bone. Points of occlusion between the tooth and this pedestal act as the fulcrum of the tooth lever system, although the position of the fulcrum is different in backward and forward bending. In lingual bending, the tooth can be pushed back on the lingual fulcrum with very little effort. In labial bending, the pedestal and tooth have interlocking grooves for stability at the labial fulcrum point, and an inelastic ligament prevents labial bending past this occlusal surface. These morphological features form a "locking" mechanism, which requires substantial force (greater than 27.3 N) to overcome. Additionally, some Lophius teeth are ankylosed to the jaw, allowing for comparisons of both hinged and unhinged tooth types within the same individuals. We found that ankylosed teeth are smaller and less variable in size compared to the hinged teeth, although they overlap in size. We are also applying techniques such as micro-CT, mechanical testing, and histological sectioning to add to our understanding of the anatomy and function of these teeth.

93-6 OHRNBERGER, SA*; HAMBLY, C; SPEAKMAN , JR; VALENCAK, TG; University of Veterinary Medicine Vienna, University of Aberdeen, University of Aberdeen, Chinese Academy of Sciences; *Sarah.Ohrnberger@vetmeduni.ac.at*

Golden hamsters raise large litters, produce loads of milk but suffer from heat stress

According to the heat dissipation limitation hypothesis, the extent of heat produced as a by-product of both metabolism and milk production is constraining the amount of food a female can ingest and the efficiency by which she converts nutrients into milk. Our model, the golden hamster (*Mesocricetus auratus*) produces large litters of 3-16 altricial young and transfers large quantities of milk to them during the 3-weeks lactation period. By breeding golden hamsters at three different ambient temperatures (8°C, 22°C, 30°C) we observed that subcutaneous body temperatures in lactating females were 0.5°C higher than in non-reproductive controls ($F_{1,123}$=13.6, p<0.01). We also observed that at 30°C lactation comes to a standstill with very low survival of young. Comparing milk energy output, food intake and energy assimilation at three ambient temperatures, we found they were highest at 8°, lowest at 30° and intermediate at 22°C. In the next experiment, we hypothesised that dorsal fur shaving may alleviate the heat stress. We compared energy turnover in shaved and unshaved golden hamsters and their pups. Dorsal shaving females led to an increase in pup growth: with nearly identical mean litter sizes, shaved mothers having lower faecal cortisol metabolites levels also weaned 38.5% heavier litters than litters produced by unshaved golden hamsters.

S11-8 OKAMURA, B*; HARTIGAN, A; NALDONI, J; OKAMURA, Beth; Natural History Museum, London, Universidade Federal de São Paulo; *b.okamura@nhm.ac.uk*

Extensive uncharted biodiversity: the parasite dimension

By their very nature, parasites are hidden and thus hard to sample. Consequently parasites are generally ignored in community surveys and their diversity is poorly understood despite growing appreciation of their contributions to ecosystem function and the potential impacts of parasite extinction. We highlight our limited understanding of parasite diversity and how research on parasites is biased, with the vast majority of work focusing on parasites of medical importance or on helminths and arthropods that infect vertebrate hosts (e.g. livestock and fish and game species). To address this bias and to explore uncharted parasite diversity we turn our attention to the Myxozoa - a speciose clade of endoparasitic cnidarians with complex life cycles. We compare estimates of myxozoan and free-living cnidarian species diversity and summarise our limited knowledge of patterns of myxozoan diversification and geographical distributions. We then review problems of estimating diversity of microparasites like myxozoans and evaluate similarities and differences in estimating diversity of microparasites and macroparasites. Evidence for parasite extinction and its potential knock-on effects leads us to summarise the potential implications of declines in parasite diversity.

15-6 OKUBO, RP*; LAHONDèRE, C; VINAUGER, C; RIFFELL, JA; University of Washington; *ryokubo@uw.edu*
Orchid Pollination By Mosquitoes
Many studies have extensively investigated the host-seeking behavior of female mosquitoes as disease vectors. It is also known that both male and female mosquitoes require sugar for flight and survival and yet, this aspect mosquito feeding ecology is understudied and not well understood in nature. Many mosquito species acquire sugar from plant sources such as the nectaries from flowers, but are rarely identified as major pollinators. Here, we discuss a species of snowmelt mosquito, *Ochlerotatus communis*, as the major pollinator of *Platanthera obtusata*, the blunt-leaved rein orchid. We show that the orchid is highly dependent on mosquitoes for successful fruit formation through pollination exclusion. Through a two-choice behavioral assay, we show that this unique interaction between this orchid and its pollinating mosquito species are mediated by the floral scent. We then take a morphometric approach to see if this mutualism is further specified by the morphological match between the flower structure and the head of the mosquito. Our study provides an ideal and reliable system to further understand mosquito sugar-feeding behavior in a natural context.

24-5 OLBERDING, JP*; BLOB, RW; MAYERL, CJ; ESPINOZA, NR; DEBAN, SM; University of California, Irvine, Clemson University, University of South Florida; *olberdij@uci.edu*
Frog hind limb joint contributions to jump energy across scale and temperature
Storage of energy in elastic structures can overcome limits on muscle power production and allow small animals to achieve movements rivaling those of larger ones. Elastic structures recoil with greater power than muscles can generate, effectively amplifying muscle power. They can also confer thermal robustness to behaviors that must occur at different temperatures because muscle power production is reduced at lower temperatures, but the power of a recoiling elastic structure is not. To study the interaction of power amplification and thermal robustness from elastic recoil, we examined elastically powered jumping in Cuban tree frogs (*Osteopilus septentrionalis*). We recorded high-speed video and force plate data from the jumps of 25 frogs ranging from 2-42 g, at 10 and 30°C. We used inverse dynamics to calculate the energy released by each joint (hip, knee, ankle, tarsometatarsal) and related that to the total energy produced. Based on morphology, we assumed that energy released at the hip or knee came directly from muscle, whereas energy released at the ankle or tarsometatarsal joint was stored elastic energy. We found the proportions of energy coming from each hind limb joint did not change with size. Although the largest frogs could theoretically achieve observed jump performance using only muscle, they used similar amounts of elastic recoil compared with smaller frogs. We also expected the relative contributions of elastically powered joints (ankle and tarsometatarsal) to increase at lower temperatures, but these remained constant. Cuban tree frogs of all sizes use the same mechanism to achieve similar jump performance and are similarly affected by changing temperature.

30-1 OLSEN, AM*; HERNANDEZ, LP; CAMP, AL; BRAINERD, EL; Brown University, Providence, George Washington University, Washington, DC; *aaron_olsen@brown.edu*
Closed loops of joints, rather than the joints themselves, impose the primary motion constraint in the catfish mouth expansion mechanism
Musculoskeletal systems can be classified into one of two types of mechanisms: open-chain versus closed-chain. In open-chain mechanisms, joints form open branches (e.g. vertebrate limbs) while in closed-chain mechanisms, joints connect back on themselves to form closed loops (e.g. the cranial linkages of fishes). While for both types of mechanism, motion is constrained by the individual joints, in closed-chain mechanisms the joint chains themselves impose an additional motion constraint. However, for biomechanical closed-chain systems it remains unknown which imposes a greater motion constraint: the joints themselves or the linking of joints together into a closed chain. To answer this question we collected 3D *in vivo* kinematics of seven cranial bones in channel catfish during suction feeding using X-ray Reconstruction of Moving Morphology (XROMM). We then fit single-joint and multibody models of varying degrees of freedom (DoFs) to the *in vivo* kinematics of the hyoid-pectoral girdle mechanism, which expands the mouth during suction feeding. We find that the hyoid-pectoral girdle mechanism functions as a 6-body linkage with at least 3 DoFs, revealing higher mobility than found by previous 2D kinematic studies. Yet, as an open chain the hyoid-pectoral girdle mechanism would have at least 11-12 DoFs. Thus, in this mechanism the linking of joints into a closed loop imposes the primary motion constraint, reducing the DoFs by over 70%. These results demonstrate a significant biomechanical consequence of simply connecting joints into closed chains, which may underlie a fundamental difference in the function and control of open- versus closed-chain motor systems. Funded by NSF 1612230, 1655756.

137-6 ONTHANK, KL; Walla Walla University; *Kirt.Onthank@wallawalla.edu*
Octopodium: Experiences video blogging my research on YouTube.
We are in an era in which public understanding of science is crucial to the nearly all aspects of society. Nevertheless, large segments of the American public are growing increasingly distrustful of the scientific enterprise. In particular, a general lack of knowledge of the fundamental function of the scientific process makes fertile soil for conspiracy theories like the massive collusion among scientists on issues such as climate change. To in some small way help address the widespread misunderstanding of the process of science, I began a video blog (vlog) on YouTube named "Octopodium". During the following two years I have posted thrice weekly videos following the progress of research in my lab during my summer field season. The goal of Octopodium to communicate to a non-scientist audience how scientific research is played out on a day-to-day basis. Over the course of these two years viewership has modestly but steadily increased. To date, over 100 videos have been published to Octopodium and videos on the channel have been viewed over 12,000 times. While this mode of scientific communication appears to offer a rich and in-depth view into the work of a research scientist, it can also be very time intensive. I hope sharing my experiences in this type of science communication can inspire and guide scientists interested in using this medium in the future.

5-7 ORBACH, DN*; RATTAN, S; HOGAN, M; CROSBY, A; BRENNAN, PLR; ORBACH, Dara; Mount Holyoke College, South Hadley, MA, UMass, Amherst, MA; *dnorbach@gmail.com*

Biomechanical Properties of Dolphin Reproductive Tissue

Whales, dolphins, and porpoises have unusual vaginal folds of unknown function(s) that are hypothesized to play an important role in sexual selection. The functional morphology of vaginal folds was assessed by testing the mechanical properties of common bottlenose dolphin (*Tursiops truncatus*) reproductive tract tissues in 6 different regions and across age classes in post-mortem specimens. We assessed the regional and global effective elastic modulus of tissues using indentation and tensile tests. Age class, tissue type, type of force, and force values significantly affected the effective elastic modulus. The tissue was stiffest in the vaginal fold region and overall stiffer in sexually immature compared to mature animals. Reproductive tract tissue may increase in elastic modulus resulting from distension associated with copulation and parturition. Our data, combined with observations of mechanical interactions of genitalia during simulated copulation, suggest that the vaginal folds function as mechanical barriers to the penis and may provide females with mechanisms to control paternity.

P3-88 ORR, TJ; HAYSSEN, V*; University of Utah, Smith College; *teri.orr@utah.edu*

Misconceptions about conception and other fallacies

Although commonly considered passive players, female animals possess extraordinary control over their reproduction using diverse mechanisms. They regulate major aspects of mating and conception as well as offspring survival, growth, and development. Yet, historically, the female perspective has been given short shrift. One of the most striking aspects of historical terminology is that features of indeterminate sex may be given male names. For example the embryonic genital tubercle is often referred to as a primordial phallus. Even adult female structures may be given male names, such as the enlarged clitoris (aka "pseudopenis") of female hyenas or the "female" prostate. Recent terminology is not exempt from historical biases. For instance, the the robust anatomy of a female cave insect (Neotrogla) is described as a female penis. In an unusual methodological twist, male traits have historically been employed to measure female behavior. Two particularly interesting cases include "induced" versus "spontaneous" ovulation and estrus. Our poster reviews specific examples across taxa of how the historical perspective in reproductive biology has led us to, in some cases, misunderstand that biology. We offer alternatives to help move the field forward in a gender-neutral way.

131-4 ORR, TJ*; KITANOVIC, S; SCHRAMM, KM; SKOPEC, MM; WILDERMAN, PR; HALPERT, JR; DEARING, MD; University of Utah, Weber State University, Weber State University, University of Connecticut; *teri.orr@utah.edu*

The Role of Cytochrome P450 2B (CYP2B) in Facilitating Dietary Specialization in Mammalian Herbivores

Although herbivory is a common strategy in mammals, few species display dietary specialization likely because of limitations in metabolizing high levels of similar plant secondary compounds in a single plant species. To advance our understanding of dietary specialization, we investigated aspects of hepatic metabolism in a juniper specialist, *Neotoma stephensi* (diet >85% *Juniperus monosperma*), in comparison to a generalist, *N. albigula* (diet ≤30% juniper). We conducted juniper feeding trials with woodrats and measured the protein content and sequence diversity of a key detoxification enzyme, cytochrome P450 2B (CYP2B). We also measured microsomal turnover of α-pinene, the most abundant terpene in *J. monosperma*. In both species, addition of 30% juniper to the diet increased CYP2B expression (2.5 fold) and α-pinene turnover rates (4-fold). In the specialist, higher levels of dietary juniper (60%, 85%) further induced CYP2B and increased α-pinene turnover rates. Although no species differences in feeding or α-pinene turnover rates were observed at 30% dietary juniper, CYP2B protein levels were 1.7-fold higher in the specialist relative to the generalist ($p<0.01$). Similarly, the specialist possessed ~5 more CYP2B gene copies, and despite greater copy number, exhibited less CYP2B sequence diversity. Because the generalist does not consume more than 30% juniper, it is unknown if this species lacks the ability to further increase expression of CYP2B or other enzymes that metabolize α-pinene. However, the increased CYP2B content and α-pinene turnover rates in generalists exposed to 60% or 85% juniper suggest CYP2B enzymes support this species' ability to specialize on juniper.

43-3 ORTEGA-JIMENEZ, VM*; COMBES, SA; Univ. of California, Davis; *ornithopterus@gmail.com*

Living in a Trash Can: Drosophila Flight Control in Turbulent Convection Cells

Rayleigh-Bénard convection cells, which are widespread in nature, are flow instabilities driven by a thermal gradient between a heated surface and its surroundings. For flying insects that live in urban environments, these perturbed flows represent a challenge because artificial surfaces exposed to solar radiation can reach extreme temperatures (up to 100 ºC), generating significant unsteady flows. We examined the effect of thermal convection cells on fruit flies (*Drosophila melanogaster*), which inhabit urban environments and fly close to surfaces on which convection cells may form. We performed repeated measurements on individual flies ($n=32$) to compare their performance when flying across a chamber ($22 \times 12 \times 8$ cm) through still air and through turbulent convection cells ($Ra \sim 10^7$ and $Pr \sim 0.7$). In general, flight performance declined when flies were exposed to turbulent convection conditions: 34 % of individuals experienced flight control losses and fell to the ground, and 50% reached their target but displayed lower average speeds than during control flights. While some wing kinematics were affected at the end of the trial in these individuals, average pitch angle was steeper in the presence of turbulent convection, and mass-specific mechanical energy was lower. In contrast, the remaining 16% of individuals displayed improved flight performance (higher speed, acceleration, and kinetic energy) during perturbed conditions, and their trajectories show that they took advantage of the flows generated by convection. Our results suggest that although turbulent convection represents a serious control challenge for insect fliers, it can be advantageous if insects choose a trajectory that allows them to effectively extract energy from these environmental flows.

P2-253 ORTEGA-JIMENEZ, VM; CUELLAR, R*; VAYSTUB, J; COMBES, SA; Univ. of California, Davis; *racuellar@ucdavis.edu*

How Do Unsteady Flows Influence Ecological Interactions?

Turbulence is a major atmospheric feature within the planetary boundary layer, influenced by weather, topography, vegetation, and convection processes. Under these challenging conditions, flying animals engage in intra- and inter specific interactions in order to feed, mate, and escape from predators. Previous experiments examining the effect of perturbed flow on individuals suggest that vortex size, turbulence intensity, and vortex decay are important factors that influence flight control, stability and energetics of flying animals. However, the effect of perturbed flows on ecological interactions remains largely unexplored. Here, we discuss the possible effects of perturbed flows on ecological interactions, based on recent evidence from the literature, as well as from experiments on predator-prey interactions between damselflies and fruit flies in turbulent flows. We conclude that unsteady flows can influence ecological interactions, particularly when the participants differ in body size. Thus, perturbed flow environments may play an important and previously unrecognized role in ecological processes such as foraging, habitat selection, predation, and mating.

49-4 OTHAYOTH, R*; LI, C; Johns Hopkins University; *ratan@jhu.edu*

Cockroaches change locomotor modes to traverse beam obstacles of varied stiffness

Recent laboratory studies begin to reveal how animals move in complex 3-D terrains common in nature. For example, to traverse grass-like beam obstacles with uniform flexural stiffness, cockroaches can push through, climb over, roll its body to maneuver through slits, or even transition between multiple locomotor modes. However, we know little about what governs animals' use of diverse locomotor modes in more natural environment where terrain properties vary spatio-temporally during locomotion. Here, to begin to address this question, we studied how beam traversal of the discoid cockroach (*Blaberus discoidalis*) depended on beam stiffness, by developing a new platform to precisely control and vary beam stiffness and automatically track animal and beam movement during locomotion. We discovered that the animal's dominant traversal mode and thus traversal performance depended sensitively on the stiffness ($P < 0.001$, repeated-measures ANOVA). For the least stiff beams, the animal frequently (95 ± 5 %) pushed the beams down and continued running with little change in gait, and quickly traversed (1.1 ± 1.1 s). As beams become stiffer, the animal more often (90 ± 6 %) rolled its body to maneuver through slits between beams, and traversed less quickly (2.7 ± 1.4 s). A locomotion energy landscape model revealed that, regardless of beam stiffness, the animal always more often traversed using the locomotor mode that overcomes the lower potential energy barriers. Our study demonstrated animals' ability to adjust locomotion behaviors and strategies in response to the changing environment, and is a first step towards discovering principles of locomotor transitions in nature. Our results also support the vision that locomotion energy landscapes will allow understanding and prediction of locomotor transition pathways in complex 3-D terrains.

S10-1 OUYANG, Jenny*; DOMINONI, Davide; University of Nevada, Reno, Netherlands Institute of Ecology, NIOO-KNAW; *jqouyang@gmail.com*

Introduction to symposium: Behavioral and physiological adaptation to urban environments

As urban areas continue to grow, understanding how species respond and adapt to urbanization is becoming increasingly important. Knowledge of the mechanisms behind observed phenotypic changes in urban animals will enable us to better judge the impact of urbanization on current and future generations of urban wildlife while also shedding light on how animals respond to novel environments. In the past decade, urban ecology has emerged as a means of understanding organismal adaptation but also as a framework for exploring mechanisms mediating evolutionary phenomena. This symposium will bring together leading experts in ecology and evolutionary biology who work in a broad range of taxa using innovative techniques. The overarching goals of this symposium are to: 1) develop an integrative framework for characterizing and predicting individual and population responses to urbanization at a larger and longer-term scale, one that will guide and inspire the field of behavioral and physiological adaptation; 2) development of an experimental approach to the study of urban eco-physiology which has been so far largely lacking; 3) integrate physiological mechanisms with behavioral studies for individual-based characterization of urban adapters or avoiders; 4) develop new connections between SICB and the larger community of ecologists whose work involves urban ecology.

28-4 OYEN, KJ*; PRATHER, JF; HERNDON, JD; STRANGE, JP; DILLON, ME; University of Wyoming, Utah State University, USDA-ARS-Pollinating Insect Biology, Management and Systematics Research Unit; *koyen@uwyo.edu*

A comparison of flight muscle action potentials during chill coma onset in high and low altitude bumble bees reared in common garden conditions

At cold temperatures, insects enter a reversible state of paralysis known as chill coma. Chill coma onset (CCO) represents a key physiological and ecological threshold where insects become unable to move and therefore cannot feed, reproduce or evade predation. Maintenance of muscle function at cold temperatures may therefore allow populations to invade and persist in colder climates. Bumble bees are broadly distributed in cold climates at high latitudes and altitudes. Recent work has shown that high altitude *Bombus vosnesenskii* have lower CCOs than their low altitude counterparts. We used electrophysiological recordings to directly measure the effect of temperature on the activity of flight muscle fibers in worker bumble bees (*B. vosnesenskii*) reared in common garden conditions from queens collected at high (1619m) and low (70m) altitudes. Intracellular recordings using sharp microelectrodes revealed tonic discharge of muscle action potentials (MAPs) at room temperatures and during the onset of cold temperatures. Near CCO, bursting became more irregular, and there was a complete cessation of MAPs at CCO. These data may lead to a better understanding of the key mechanistic differences in muscle physiology underlying variation in cold tolerance among bumble bee populations.

S11-2 PADIAN, K; University of California, Berkeley; *kpadian@berkeley.edu*

Measuring and comparing extinction events: reconsidering diversity crises and concepts

Historically, most analyses of "mass extinctions" have focused on the marine realm, because most fossils are preserved there and marine sediments provide more and finer-scaled evidence of turnover and crises in biodiversity than terrestrial environments do. Because marine taxa outnumber terrestrial taxa by a margin of at least 25:1, analyses of diversity crises that have lumped all phyla and environments together, especially at the global level, have caused the terrestrial evidence to be "swamped" statistically by the marine data. Both synchroneity and causality of terrestrial and marine events have usually been assumed, without decisive data. The concept of "mass extinctions" has no definitional limits on the application of the term with respect to duration, geography, ecology, or taxa affected. Such events have little comparability, no operational definitions, and inadequate underpinnings in testable theory. Unusual drops in taxonomic diversity have traditionally focused only on increases in extinction rates, with scarce consideration (if any) of origination rates and their interplay with extinction rates. As a result, some major episodes in the history of life have been largely misinterpreted, notably the loss of some terrestrial animal groups at the end of the Permian, the Triassic, and the Cretaceous. The present diversity crisis is nothing like those of the past, and cannot be studied in the same way. Analyses of hypothesized diversity crises should be operationally and situationally defined and statistically normalized through the histories of taxa and biotas, and should always explicitly include both origination and extinction rates. The term "mass extinctions" should be abandoned and replaced by "diversity crises." These parameters require not absolute numerical (or percentage) limits but situational ones.

21-1 PADIAN, K; University of California, Berkeley; *kpadian@berkeley.edu*

How scientists tell stories: Narrative and "anti-narrative" in communicating research

Although we like to separate scientific explanation from religious myths and secular fiction and history, there are many elements in common. Misia Landau and others have pointed out the correspondence between evolutionary "origin" stories and traditional folktales, including elements of protagonists, challenges, and problem-solving. Human evolution provides many vivid examples, including some "just-so stories" famously critiqued by S.J. Gould and R. Lewontin. Evolutionary biologists have a tendency to invoke mechanisms of what natural selection "would do" or "would be expected to do," but often these inferences are neither tested nor testable, and they reduce to statements of faith, albeit different from religious statements in some important respects. How do we differentiate story-telling in science and in other domains? Alternatives to natural selection, such as those of Seilacher's Konstruktionsmorphologie, as well as the use of strong phylogenetic inference, can test such hypotheses. The order in which features related to adaptations or complex behaviors evolve in lineages provides a strong constraint on and a test of scientific narratives. Science needs stories, and the use of accepted methods and practices is an advantage over other forms of discourse and disciplines. Yet in formal scientific publications, we forego most narrative elements of our research in favor of a formulaic discourse ("anti-narrative") that obscures linear (narrative) structure and human involvement. Scientists have to work to overcome this disadvantage when explaining our research to the public: in the end, we don't talk the way we write.

95-7 PADILLA, DK*; VOLKENBORN, N; GURR, S; MILKE, L; MESECK, S; RUGILA, A; REDMAN, D; DIXON, M; VEILLEUX, D; LIGUORI, A; ROSA, M; Stony Brook University, NOAA Northeast Fisheries Science Center, Milford CT; *Dianna.Padilla@stonybrook.edu*

Population Differences In Response To Ocean Acidification In Blue Mussels

The oceans have absorbed about 26% of the released atmospheric CO_2, resulting in changes in ocean chemistry or ocean acidification (OA). Environmental parameters that impact growth and survival, including pH, can vary on short time scales in shoreline systems. It is important to know whether responses to environmental stressors are phenotypically plastic or if different populations have local adaptation to stressful environments. Traditional metrics of the effects of stress integrate over long periods of time (e.g., growth), are a snapshot of animal state (e.g., condition index), or require isolation of animals from their environment (respiration rate). However, infrared and Hall-Effect sensors allow monitoring heartbeat and valve gaping (time spent filtering) with high temporal resolution over extended periods of time, allowing us to detect the immediate metabolic and behavioral responses changes in environmental conditions. Blue mussels, *Mytilus edulis*, were collected from sites with around Long Island Sound (LIS) with different water quality conditions to test whether mussels from more stressful environments are more resilient to the impacts of OA. We found that mussels from different populations show different stress responses to OA (manipulating aragonite saturation). Mussels from eastern and western LIS had elevated heartbeat rates in response to OA, while animals from central LIS showed no response to even extreme OA conditions, suggesting site-specific resilience.

P2-183 PAEZ, VM*; COOPER, T; VOLD, T; MENDELSON III, JR; GOLDMAN, DI; Georgia Institute of Technology, Zoo Atlanta; *mpz@gatech.edu*

Initial Observations of Surface Sand Swimming in Plestidon Reynoldsi

The Florida sand skink's, *Plestiodon (= Neoseps) Reynoldsi*, use of limbs and tail in surface sand swimming and burying locomotion is of particular interest because of this animal's greatly reduced limbs. The forelimbs retain only a single digit while the hindlimbs bear two digits. Previous work suggested that forelimbs are of little use during sand locomotion (Andrews, 1994). We conducted preliminary locomotion trials using two adult skinks that we hand-captured at the Archbold Biological station, Florida. Using a Canon 600D camera, we recorded their behavior in an indoor sand-filled test arena. Preliminary observations suggest that the skink leaves characteristic tracks when swimming on the sand's surface, contradicting reports that tracks were a result of sub-surface swimming (Andrews, 1994). This suggests that both sets of limbs are actively used during locomotion and appear to move in a stereotypical gait, alternating diagonally-paired limbs. The skink also appears to generate thrust with its tail in certain sand burying situations. This often occurred when the skink dipped its head off to the side of its longitudinal axis to initiate the burying process. The tail whips anteriorly to such an extent that it may contact the side of the head, and the process is repeated on the opposite side. Based on our trials, it is plausible that the hindlimbs are used to push against the sand to help produce this whipping motion. Although the function of lateral tail whipping during burial is unclear, during the burying trials we observed ½ to 2 complete body undulations before full submersion. Early observations suggest the skink uses its reduced limbs during both surface sand-swimming and burial but more experimentation is required to determine the role of the tail and limbs.

P2-37 PAITZ, RT*; CAMPBELL, NA; ANGLES, R; BOWDEN, RM; CASTO, JM; Illinois State University; *rpaitz@ilstu.edu*

Does mother really call the shots?: Rapid in ovo and in vitro metabolism of testosterone in bird eggs

Vertebrate embryos develop within an environment containing maternal steroid hormones that are transferred during oogenesis or gestation, which may have either transient of persistent effects during embryonic development. In egg-laying vertebrates, the amount of steroids a female transfers via yolk to the eggs she lays can vary, and this variation has been hypothesized to adaptively modify offspring phenotype. Yet, embryos are known to actively regulate their maternal steroid exposure, which raises the question: How important are maternal steroids to embryonic development? In the *in ovo* study, we used European starling (*Sturnus vulgaris*) eggs to examine the fate of yolk testosterone early in development. Tritiated testosterone (3H-T) was injected into freshly laid eggs which were then sampled over the first five days of incubation to characterize the movement and metabolism of 3H-T. After only 12 hours of incubation, the overwhelming majority of the 3H-T had been metabolized. Various metabolites, primarily etiocholanalone, were detected within the yolk. We then used yolk and albumen from unincubated eggs to assess 3H-T metabolism *in vitro* and found that the patterns of metabolism within the yolk were largely similar to those reported in the *in ovo* study. Given the rapid pace at which 3H-T is metabolized, both *in ovo* and *in vitro*, the extent to which maternal testosterone ever influences the embryo prior to being metabolized is unclear. The phenotypic effects of maternal testosterone may thus be mediated by the small amount of non-metabolized testosterone, the large amount of etiocholanolone produced, or both.

P3-145 PAKZAD, IY*; KLOHMANN, CA; SCANTLEBURY, SS; SCOTT-BüCHLER, C; VOMPE, AD; FIORENZA, EA; FARINA, SC; Cornell University, Cornell University, Univ. of Washington, Harvard University; *iyp4@cornell.edu*

Identifying Ecological Correlates of Respiratory Microstructure Morphology in Sculpins (Cottoidea)

Fish gills are composed of elongate gill filaments that support microscopic gill lamellae, which are the primary site of gas and ion exchange. To understand how the morphology of these complex three-dimensional structures evolve within clades of closely-related fishes, especially in response to ecological and physiological demands, we studied the sculpins (superfamily Cottoidea). Sculpins are found in freshwater and marine habitats, and marine species can be found in the intertidal, subtidal, or deep-sea. We examined 12 sculpin species from the Pacific Northwest using scanning electron microscopy to take six measurements of the gill microstructures that capture the variation in their complex branching shape. We used phylogenetically corrected ANOVAs to test for relationships among our six measurements and two ecological parameters (tendency to be found in the intertidal and to exhibit air-breathing). We found no significant relationship among these morphological and ecological variables. However, a phylogenetically corrected principal component analysis revealed that strictly subtidal fishes occupy a morphospace defined by shorter gill filaments and shorter lamellae.

7-2 PALECANDA, S.*; PORTER, M.L.; University of Hawai'i at Manoa ; *spalecan@hawaii.edu*

Shifts in Opsin Expression During Larval Development in Pullosquilla thomassini (Crustacea, Stomatopoda)

Stomatopods possess one of the most intricate visual systems in nature. Their stalked eyes move independently and have multiple spectral and polarization channels. Amazingly the complex retina responsible for these abilities is only formed during the last phase of larval development during which time the larval retina is lost. It has been assumed that the eyes of larval stomatopods are far less complex than their adult counterparts, however our study shows that this might not be the case. Using transcriptomic analyses we have determined the opsin proteins which are expressed at embryonic, larval, and adult developmental stages of *Pullosquilla thomassini*, a species with the most complex of adult stomatopod eye types. With this information, we compared patterns of opsin expression between developmental stages to give more insight into the shift from larval to adult vision. Transcriptomes of retinal tissue from 6 different developmental stages were sequenced and opsins were identified. Our data suggests that *P. thomassini* possess a total of 31 opsins with all but one being expressed in the adult retina. 17 long wavelength sensitive, 12 middle wavelength sensitive, and 2 UV sensitive opsins were identified using phylogenetic methods. The number of opsins expressed increased throughout development with major shifts corresponding to physiological and environmental changes, most notably the appearance of characteristic larval eye shine. Expression levels (TPM) indicated most opsins increased in expression through development or peaked during formation of the adult retina. However, we found several opsins which were more highly expressed in the larval retina. Ongoing work will seek to characterize differential expression of a suite of rhabdomeric developmental genes as well as pigment pathways.

P1-178 PALMERSHEIM, MC*; HELM, BR; ROYAUTE, R; MALLINGER, RE; YOCUM, G; North Dakota State University, Fargo, USDA-ARS, Fargo; *michala.palmersheim@ndus.edu*

Sub-Lethal Effects of Neonicitinoids on the Alfalfa Leafcutter Bee, Megachile rotundata

Neonicotinoids are commonly used pesticides in U.S. agriculture. For many beneficial insect species, lethal effects of neonicotinoids are well-documented; however, much less is known about sublethal exposure. The alfalfa leaf cutter bee *Megachile rotundata* is a managed pollinator that constructs complex nests for its young. Nest construction requires a sequence of behaviors that could be affected by neonicotinoid exposure even when dosages are sufficiently low to avoid mortality. Our goal was to determine whether sub-lethal neonicitinoid exposure alters nest construction in adult female *M. rotundata*. We first determined the LD50 of imidacloprid—a common neonicotinoid used in alfalfa and other *M. rotundata*-pollinated crops. We observed lethal effects at doses of ~50ppm, which was lower than previously determined through topical application. Nesting success was measured by releasing adult females into field cages after exposure to 1ppm imidicloprid in sucrose solution (treatment) or sucrose solution (control) for 24 hours. Treated females did not complete any nests while control females built significantly more fully completed nests. We then performed an acetylcholinesterase assay to measure the duration of imidacloprid intoxication. However, we observed no upregulation of acetylcholinesterase activity following imidacloprid exposure. Thus, sub-lethal doses caused behavioral effects without enzymatic upregulation of acetylcholinesterase. In conclusion, these results suggest a higher sensitivity to neonicotinoids than previously suspected for *M. rotundata*, including substantial consequences on nest-building behavior.

40-4 PALUH, DJ*; STANLEY, EL; BLACKBURN, DC; Florida Museum of Natural History; *dpaluh@ufl.edu*

Convergent Evolution and Function of Hyperossification in Frogs

Within fossil and extant anuran amphibians, a reoccurring trend in skull morphological diversity is hyperossification, i.e. the increased mineralization and excessive ossification of a skeletal element that results in dorsal sculpturing and pitted ornamentation of dermal bones. There is little research on the evolution of anuran skull hyperossification, but a preliminary survey of skeletal diversity has indicated that it has persisted or independently evolved in at least ten families of frogs in taxa ranging in size from 16 to 245 mm snout-vent length. Three disparate hypotheses exist on the function of hyperossification—water balance enhancement in arid environments, protection against predators during phragmotic behavior, and increased skull biomechanic capabilities related to feeding biology—but there have been no explicit tests whether there is an association between hyperossified skull shape and these different functions. We utilized high-resolution micro-computed tomography and 3-D geometric morphometric analysis to determine if there is a significant difference in shape between hyperossified and non-hyperossified skulls across all families of frogs. We then further tested if a predicted relationship exists between hyperossified skull shape, the habitation of arid environments, the use of phragmotic defensive behavior, and a carnivorous diet. Further, we conducted finite element analyses on a diversity of frogs to test if species that possess a hyperossified skull generally perform better at resisting high loads of stress, strain, and deformation compared to taxa that lack hyperossification, which would suggest higher protection against predators and higher bite forces and the ability to consume larger and harder prey.

S8-10 PAN, B*; HOLT, JR; Boston Children's Hospital, Harvard Medical School; *bifeng.pan@childrens.harvard.edu*

TMC1 Function in Hair Cell Mechanotransduction

Hair cell sensory transduction was first characterized ~40 years ago. Although electrophysiology of hair cell sensory transduction has been studied intensively, the molecular basis of hair cell transduction remains unclear. Over the past 30 years, scientists have sought to identify the fundamental protein that converts sound stimuli into electrical signals in hair cells. Several candidate proteins have been suggested to be involved in hair cell transduction, but most do not match the biophysical properties of hair cell transduction channels. Recently, TMC1 and TMC2 were found to be required for conventional sensory transduction in mammalian hair cells, and may be components of hair cell transduction channel. Although the exact function of TMC proteins has been controversial, a growing body of evidence suggests TMC1 may be a pore-forming subunit of hair cell transduction channel. For this presentation, I will discuss the evidence that supports a role of for TMC1 in hair cell sensory transduction and will discuss evidence that supports alternate hypotheses for TMC1 function. Lastly, I will discuss future directions in hair cell research that may help resolve the controversy and reveal a definitive role for TMC1 in hair cell sensory transduction.

68-5 PANDORI, L.L.M.*; SORTE, C.J.B.; University of California, Irvine; *lmcquinn@uci.edu*

The Weakest Link: Climate Change Vulnerability across Life Stages of Marine Invertebrates

A great challenge in the Anthropocene is predicting the effects of climate change on Earth's biota. This challenge becomes more complex when considering species with complex life cycles, which includes 80% of the Earth's species. We utilized a meta-analytic approach to compare vulnerability to climate change across life stages of marine invertebrates. We searched ISI Web of Science for papers which examined the effects of both near-future (year 2100) and extreme warming, acidification, and hypoxia projections on the survival of multiple life stages (embryo, larva, juvenile, and adult) of marine invertebrates. We extracted data from 34 studies and calculated the difference in effect size (LRR) using both unpaired and paired analyses, given our inclusion of only studies that investigated 2+ life stages. All significant effects of climate change were negative, with warming and hypoxia affecting younger life stages more negatively than older life stages. Taxonomy and habitat also significantly affected the difference between life stages. Results of this study suggest that earlier life stages are often "weak links" in marine invertebrate life cycles and should be a focus of efforts to better predict the effects of climate change on population dynamics.

P3-226 PAPETTI, C*; BABBUCCI, M; HARMS, L; LUCASSEN, M; DETTAI, A; AUVINET, J; HEINDLER, FM; PATARNELLO, T; NEGRISOLO, E; University of Padova, Padova, Italy, Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research, Bremerhaven, Germany, Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research, Bremerhaven, Germany, Institut de Systematique, Evolution, Biodiversité, Paris Cedex, France, Université Paris 6, Sorbonne Universités Cassan, Paris Cedex, France, KU Leuven, Laboratory of Biodiversity and Evolutionary Genomics, Leuven, Belgium; *chiara.papetti@unipd.it*

The Evolution of Mitochondrial Genomes of Notothenioid Fish

There is much evolutionary and biological interest in the processes that shaped Antarctic notothenioid fish's adaptations via molecular changes. We investigated the evolutionary pathways that produced the diversity of gene orders observed in the mitochondrial genomes (mtDNAs) of these organisms. Antarctic notothenioids exhibit translocations of *nad6* and *trnE* genes in different positions with respect to the standard vertebrate gene order. We sequenced the mtDNAs of 14 Antarctic notothenioids and 1 species with sub-Antarctic distribution. We analysed a big dataset including notothenioid mtDNAs already available in public databases and a broad set of outgroups, encompassing several mtDNAs of other Perciform species. A molecular phylogenetic analysis, based on Bayesian and maximum-likelihood methods, provided a strongly supported notothenioid tree used to map the evolution of gene order in these peculiar fishes. The analysis was completed with the study of the molecular evolution of single mitochondrial genes. In a modern era, when sequencing of large genomes has become a state-of-the-art, this study demonstrates that small compact mitochondrial genomes still embed a large amount of information that advanced analytical approaches can bring to light.

S1-10 PAPS, J; University of Essex; *jpapsm@essex.ac.uk*
Reconstructing The Genome Of The First Animal: The Impact Of Novelty In The Origins Of Metazoans
The Animal Kingdom displays a stunning diversity, result of millions of years of evolution. How did single cell microbes become animals with multiple cells? How was the transition from animals such as sponges, with a topside and downside but no front and back, to creatures as us with a front and a back end and an upside and downside? Nowadays the plethora of new genomic data can be exploited to tackle these critical questions on the genesis and evolution of metazoans. We have compared more than 60 genomes belonging to 13 animal phyla and 8 eukaryotic outgroups. This dataset and the analyses performed pay special attention to the taxon sampling, selection of outgroups, and the automatic assignment of gene homology. Moreover, we developed new bioinformatic tools to trace back the origins of genes in the gnarls of the Tree of Life of animals. We show how this pipeline is able to pinpoint genes playing a major role in the dawn of animals, most of them tightly related to classical hallmarks of the origins of multicellularity, but others pointing to unforeseen functions that might be vital to our understanding of the rise of the Animal Kingdom. Some of the genes found have been previously related with the beginnings of animals, proving the predictive power of our approach. However, we also find other genes not related before with the origins of Metazoa, but that hold biological functions that make a huge biological sense in the context of that transition.

128-7 PARK, NP*; ZHANG, Y; HOOD, WR; KAVAZIS, AN; Auburn University; *nrp0012@auburn.edu*
Oxidative DNA Damage and Repair in response to induced ROS exposure in Mice
Reactive oxygen species (ROS) can damage mitochondrial and cellular proteins, lipids and DNA and thus, many consider ROS to be consistently harmful. Yet, mitochondria have developed an intricate defense system to mitigate the deleterious effects of ROS and repair damage. Associated with the defense system, mitochondria are hypothesized to display a biphasic response to ROS exposure that is referred to as mitochondrial hormesis, where modest levels of ROS signal increase d mitochondrial biogenesis, antioxidant production, and cell repair of damaged proteins, lipids and DNA. A previous study in our lab characterized the temporal response to induced ROS production in mice via X-irradiation exposure and found that oxidative damage markers for proteins and lipids initially increased and but then dropped to below control levels within 10 days in the liver, heart, skeletal muscle, and brain. The focus of this study is on the damage inflicted upon DNA from ROS. Specifically, we studied temporal changes in oxidative DNA damage and repair associated with ROS exposure via X-irradiation. One of the most stable yet pernicious results markers of oxidative DNA damage is 8-oxo-7,8-dihydroguanine, which results in the transversions of G:C to T:A during replication if not repaired. The primary enzymes involved in repair of this DNA damage are DNA glycosylases, namely 8-oxoguanine glycosylate (OGG1). With this study, we will describe the temporal changes in oxidative DNA damage and repair associated with ROS exposure via X-irradiation. In liver, DNA damage followed the hormetic pattern found in other organs, with the 10-day time-point dropping below the control level ($P = 0.022$). DNA damage and repair enzyme OGG1 levels in liver, heart, skeletal muscle, and brain will be described.

31-4 PARK, E*; WASSERMAN, SM; Wellesley College; *epark9@wellesley.edu*
Visuomotor reflexes differ in two Drosophila species
A natural environment contains an abundance of sensory stimuli. To generate adaptive behavioral responses to those stimuli, animals must quickly identify salient features, assign them an attractive, neutral, or aversive value, and ignore background noise. We investigated whether two species of *Drosophila*, native to visually distinct environmental landscapes, demonstrate varied visuomotor reflexes. Previous studies have shown that while *D. melanogaster*, native to forested areas with complex visual scenes, fixate long, thin bar-like objects that emulate landing perches, assigning these objects an attractive value; in contrast, they will steer away from smaller, box-like objects that mimic predators, for an aversive assignment (Maimon et al., 2008). Cactophilic *D. mojavensis*, however, originate from the Baja California-Mojave Desert regions with sparse visual scenery. We asked whether the size-correlated value assignments *D. melanogaster* assign are conserved across species by examining *D. mojavensis*. To investigate this question, we used a ‘virtual-reality' flight simulator to present visual objects that *D. melanogaster* consider aversive (small box) or attractive (long stripe) and presented them to tethered flying *D. mojavensis* while analyzing their steering behaviors. We found that unlike *D. melanogaster*, *D. mojavensis* steer towards small box-like objects. Additionally, *D. mojavensis* steer more robustly and find objects in elevated regions of their field of view to be more salient. These results reveal a previously unknown diversity in visuomotor processing among species of *Drosophila* and suggest that two closely-related species perform inverse behaviors in response to the same visual stimuli.

108-7 PARKINSON, RH*; LITTLE, JM; GRAY, JR; University of Saskatchewan; *rachel.parkinson@usask.ca*
A sublethal dose of a neonicotinoid insecticide impairs motion detection and avoidance behaviour in Locusta migratoria
Neonicotinoid insecticides are used extensively in agriculture in North America, despite known environmental impacts. These insecticides affect foraging behaviour and navigation in non-target insects, although the mechanisms of these effects are not fully understood. A visual motion sensitive neuron in the locust (*Locusta migratoria*), the Descending Contralateral Movement Detector (DCMD), integrates visual information and is involved in eliciting escape behaviours. The DCMD receives coded input from the compound eyes and synapses with motorneurons involved in flight and jumping. We show that imidacloprid (IMD), a neonicotinoid insecticide, impairs neural and behavioural responses to visual stimuli at sublethal concentrations, and these effects are sustained two and twenty-four hours after treatment. Exposure to 10 ng/g IMD (ng IMD per g locust body weight) attenuates escape manoeuvers while 100 ng/g IMD inhibits the ability to fly and walk. Behavioural effects correlated with attenuated neural responses: IMD disrupted DCMD bursting, a coding property important for motion detection. Specifically, IMD reduced the DCMD peak firing rate within bursts at ecologically relevant doses of 10 ng/g. Thus, IMD causes significant and lasting impairment of an important pathway involved with visual sensory coding and escape behaviours at ecologically-relevant doses. These results show, for the first time, that a neonicotinoid insecticide directly impairs an important, taxonomically conserved motion-sensitive visual network.

P3-85 PARKINSON, KJL*; HENNIN, HL; JANSSEN, MH; GILCHRIST, HG; LOVE, OP; University of Windsor, Ontario, Evironment and Climate Change Canada, Ontario, Evironment and Climate Change Canada, Ontario; *parkin11@uwindsor.ca*

Does environmental variation influence incubation patterns in an Arctic seaduck?

Climate change may limit the ability of individuals to reproduce successfully, with downstream impacts on population demography. Polar species are now faced with rates of warming much higher relative to other ecosystems, potentially placing them at even greater risk than previously expected. Unfortunately, it is unclear whether mechanisms at the heart of key reproductive decisions have the inherent flexibility that will enable individuals (and hence populations) to stay ahead of this rapid change. In waterfowl, ambient temperature can influence a mother's incubation behavior, which in turn can affect the post-hatch success of offspring. Here we test links between environmental variation and incubation parameters in Arctic-breeding common eiders, a species which faces multiple constraints during incubation. Females live in a highly stochastic environment, fast during the entirety of incubation, and yet must control the incubation period carefully so that duckling hatching matches the timing of sea ice break-up. From 2014-2016, we collected local climate data (i.e., ambient temperature, humidity, etc.) and paired this with data loggers to monitor the incubation temperatures of eider hens at East Bay Island, Nunavut, Canada. We aim to relate inter- and intra-individual variability in incubation temperatures to environmental parameters to examine whether and when hens adjust incubation decisions and their body temperature in response to fluctuating ambient temperatures. Determining the capacity of individuals to flexibly adjust reproductive decisions in response to changing environmental conditions further allows us to predict whether certain populations (and hence a given species) have the capacity to persist in response to climate change.

S7-9 PARRISH, J K*; BURGESS, H; WELTZIN, J; FORTSON, L; WIGGINS, A; University of Washington, U.S. Geological Survey, University of Minnesota, University of Nebraska; *jparrish@uw.edu*

Elevating the Science in Citizen Science: Five Steps to Rigorous Public Involvement in Scientific Research

Citizen science is a growing phenomena. With millions of people involved and billions of in-kind dollars annually, this broad extent, fine grain approach to data collection should be garnering enthusiastic support in the mainstream science and higher education communities. However, many academic researchers display distinct biases against the use of citizen science as rigorous information. We use the Coastal Observation and Seabird Survey Team (COASST), a citizen science project focused on beached birds and marine debris, to highlight five steps to bonafide science in citizen science. Defining a science-based typology focused on the degree to which projects deliver the type(s) and quality of data/work needed in scientific endeavors is a first step. Understanding the opportunities and challenges of designing and implementing a citizen science project as aligned with, but fundamentally different from, the academic paradigm is step two. Step three is realizing who your target public audience is, and what their needs, interests and values are relative to yours. Step four is intentional design to take advantage of scale- and task-dependent quality assurance and quality control procedures including embedded assessment of participant accuracy. The fifth and final step is inclusion of a layered feedback system, partially leveraged from scientific products, that elevates participant understanding of scales of pattern and forcing beyond their own experience.

38-2 PARSLEW, B*; SIVALINGAM, G; CROWTHER, W; The University of Manchester; *ben.parslew@manchester.ac.uk*

Stability and Dynamics of Avian Jumping Take-Off

A jumping take-off is an effective means of becoming airborne: using the legs to push from the ground generates greater body accelerations with reduced energy consumption compared to using aerodynamic forces on wings. The apparent ease with which a bird performs this efficient maneuver stems from the perceived success rate of jumps in nature. But attempts to recreate this process through theoretical or experimental models reveal numerous possible modes of failure, including slipping, toppling, and tumbling. In this study we develop analytical and computational models that explain these failure modes, and propose how they are avoided by birds in nature. We illustrate both successful and failed jumps using simple jumping robots and animations from computer simulation. The computational models incorporate leg kinematics taken from experiments on real jumping animals. Therefore, as a secondary output the model provides quantitative predictions of mechanical forces, torques and power consumption in jumping animals.

42-1 PASK, GM*; SLONE, JD; MILLAR, JG; DAS, P; MOREIRA, JA; ZHOU, X; BELLO, J; LIEBIG, J; ZWIEBEL, LJ; RAY, A; Bucknell University (present), Univ. of California, Riverside, Vanderbilt University, Univ. of California, Riverside, Univ. of California, Riverside, Arizona State University; *g.pask@bucknell.edu*

How to Smell Your Sisters: Detection of Cuticular Hydrocarbon Pheromones in Ants

Eusocial insects use cuticular hydrocarbons as components of pheromones that mediate social behaviours, such as caste and nestmate recognition, and regulation of reproduction. In ants such as *Harpegnathos saltator*, the queen produces a pheromone which suppresses the development of workers' ovaries and if she is removed, workers can transition to a reproductive state known as gamergate. Here we functionally characterize a subfamily of odorant receptors (Ors) with a nine-exon gene structure that have undergone a massive expansion in ants and other eusocial insects. We deorphanize 22 representative members and find they can detect cuticular hydrocarbons from different ant castes, with one (HsOr263) that responds strongly to gamergate extract and a candidate queen pheromone component. After systematic testing with a diverse panel of hydrocarbons, we find that most *Harpegnathos saltator* Ors are narrowly tuned, suggesting that several receptors must contribute to detection and discrimination of different cuticular hydrocarbons important in mediating eusocial behavior.

61-8 PATEK, S.N.*; SUTTON, G. P.; KUO, C. Y.; TEMEL, F. Z.; WOOD, R. J.; Duke, Bristol, Harvard; *snp2@duke.edu*

Elastic energy delivery and power amplification of trap-jaw ant strikes

Trap-jaw ants strike with such extreme accelerations and speeds that they must use springs, rather than muscles, to power their movement. Therefore, elastic energy storage structures and the mechanism for delivering elastic energy are both essential to understanding how mandible strikes are actuated. We measured the kinematics and morphology of *Odontomachus brunneus* (Ponerinae) trap-jaw ants and quantified the energetics and power of their mandible strikes. We tested whether the adductor apodeme or the head capsule served as the primary elastic energy storage structure and calculated their relative elastic strains. We found that each individual mandible has 24.2 ± 6.0 µJ of elastic energy delivered to it in no more than 77.1 ± 7.4 µs during a strike. The mandibles struck at up to 64 m/s and 10^6 m/s^2 with a power density of 10^5 W/kg. To drive this motion, the mandible moment arm needs to be translated at least 138 ± 13 µm by the displacement of the elastic structures. The head capsule recoiled at least 105 ± 18.6 µm (with 64 ± 14.5 µm in the anterior head capsule and 41 ± 8.9 µm in lateral sides of the head capsule), yielding at least 76% of the necessary strain. Therefore, the head capsule stores the majority of the needed energy and the apodeme most likely provides the rest. In conjunction with these measurements, we also developed a forward dynamic model that matches the mandible kinematics and estimates spring stiffness and damping. Our finding of elastic energy storage via head capsule deformation rather than through apodeme stretching offers insights into the shifting roles of tendon-like structures as struts versus springs in animal movements, particularly in the context of loading and length scale in spring-actuated systems.

P1-42 PATEL, T*; RIMKUS, B; KONOW, N; UMass Lowell; *trushti_patel@student.uml.edu*

Influence of Recruitment Level on Jaw Muscle Operating Lengths During Chewing

For feeding muscles, our understanding of the operating length-ranges with respect to optimal length (L_o, where isometric peak force is generated) are based on twitch contraction studies of whole jaw muscles. These studies suggest that jaw muscles operate at short lengths on their length-tension (LT) curve. However, muscles are rarely twitch recruited *in vivo*, and in pennate muscle, fiber contractile behavior may differ from whole muscle behavior. Recent limb muscle data reveal variations in L_o with recruitment level, but the effect of recruitment on *in vivo* operating length of feeding muscle remains unknown. We measured fiber length change, muscle activation, and muscle force from rat deep masseter, a key jaw elevator, during food processing. An *in situ* approach was then used to construct LT curves for twitch (minimal), sub-maximal (intermediate), and tetanic (maximum) stimulation conditions. This combined approach revealed how *in vivo* fiber operating lengths are shaped by recruitment level and LT effects. Based on recent limb muscle data, we predicted L_o to be shortest for tetanic, intermediate for sub-maximal, and longest for twitch contractions. In line with our prediction, tetanic L_o was approx. 17% shorter than twitch L_o. The LT curve for skeletal muscle describes a trade-off between weak but stable contractions at short lengths, peak force production at intermediate lengths, and weak as well as unstable contractions at long lengths. In contrast to twitch data from earlier jaw muscle studies, our data suggest that chewing at wide gape on hard food may render jaw muscles vulnerable to sarcomere instabilities as they are forced to operate at long, weak, and unstable lengths. These results have implications for determining potential causes of oral physiological dysfunctions.

114-5 PATEL, RN*; CRONIN, TW; University of Maryland, Baltimore County; *rickp1@umbc.edu*

Navigating the Benthic Reef: Path Integration and Landmark Orientation in a Mantis Shrimp

Stomatopods, better known as mantis shrimp, are predatory crustaceans which commonly inhabit holes and crevices in benthic marine environments for use as burrows. However, many stomatopod species forage at extended distances from these burrows before returning back to their homes, risking predation. Since many mantis shrimp are central place foragers living in structurally complex environments, we hypothesized that these animals use piloting (landmark navigation), path integration (dead reckoning), or a combination of the two methods to navigate their benthic environments. To experimentally determine which mechanisms are employed, *Neogonodactylus oerstedii* were placed in featureless circular arenas in a glass roofed greenhouse, with their burrows submerged from view. Foraging paths in the presence and absence of a landmark adjacent to the burrow were recorded. We found that return trips in the presence of the landmark were more direct than trips in the landmark's absence. However, the initial direction of the return trips were generally oriented towards the burrow regardless of the presence or absence of the landmark. Further, in the absence of a landmark, paths home were statistically indistinguishable to the beeline distance to the burrow before a search behavior was initiated. To determine if *N. oerstedii* employ path integration when returning to their burrows, animals were translocated along a platform to a new location before homeward paths were initiated. These translocated animals exhibited homeward paths oriented towards the direction of the burrow had they not been moved, rather than towards the actual direction of their burrow. These results indicate that *N. oerstedii* use piloting in parallel with a path integration system to return to their burrows.

46-7 PATEL, RG*; KENNEDY, EBL; CLUBB, BL; UYENO, TA; CLARK, AJ; College of Charleston, Valdosta State University, Valdosta State University; *patelrg@g.cofc.edu*

Comparative Biomechanics of Diverse Hagfish Skins

The slack skin of hagfishes may enhance maneuverability (e.g. body knotting or squeezing through tight spaces) and resist puncture. Hagfish skin facilitates forming and manipulating body knots because its baggy fit decouples the otherwise restrictive skin from the muscles and viscera of the body core. Previously, the skin of the Pacific hagfish (*Eptatretus stoutii*) has been shown to be as strong and stiff as the taut skins of other fishes, but with one difference: hagfish skin is significantly more compliant in the circumferential axis. This anisotropy may facilitate extreme body torsions needed to produce a knot. It is unclear if the morphology and material properties are conserved across the skins of other hagfishes. Here, we use quasi-static uniaxial tensile tests and histology to investigate the material properties and morphology of the skins from four hagfish species, two Eptatretines (*E. stoutii*, *E. springeri*) and two Myxinines (*Myxine glutinosa*, and *M. hubbsi*). Across all hagfish species, the skins are comparable in thickness, stiffness, strength, extensibility, and toughness. However, in contrast to *E. stoutii* skins, the skins of all other hagfish species tested are isotropic, being equally resistant to strains applied along longitudinal and circumferential body axes. Histological data show an abundance of contractile fibers in the dermis of the Eptatretines but a conspicuous absence in the dermis of the Myxinines. These hagfish species exhibit notably different knotting and resting behaviors, with *E. stoutii* coiling their bodies at rest and forming the tightest body bends during knotting. We propose that these behavioral differences across species may be associated with variation in the form and function of the skin and notochord.

P2-84 PATTON, ST*; CLAY, DY; JACOBS, EP; MARIAS, M; GIBBS, AG; Nevada State College, UNLV, SUNY Fredonia, Georgetown Univ; *allen.gibbs@unlv.edu*
Effects of Diet on Genetically Obese Drosophila
Over 90 generations of selection for starvation resistance in outbred populations of *Drosophila melanogaster* have resulted in flies that are extremely obese, even when fed a standard *Drosophila* diet. Obesity can also be induced in normally lean flies by rearing them on a low-protein, high-sugar diet. We investigated whether starvation-selected flies respond differently to dietary changes than controls. Have starvation-selected populations reached their maximum lipid content, or can they be made even more obese through dietary manipulations? We reared starvation-selected and unselected lean control larvae on diets containing 5 yeast:sucrose ratios, ranging from 90% yeast:10% sugar (Atkins diet) to 10% yeast:90% sugar (American diet), as well as 3 different caloric concentrations. Starvation-selected and control flies had similar responses to rearing diet: development to adulthood was delayed on high sugar diets, and flies reared on high sugar diets eclosed with significantly greater lipid stores. Total protein levels were not affected, indicating that these flies were fatter, not simply larger due to extended larval feeding. To determine whether lack of micronutrients contained in yeast could have affected these results, we reared flies on high-sugar media containing vitamins, trace metals, cholesterol or RNA, as well as a combination of all of these. Lipid content did not differ from that of flies reared on un-supplemented media. We conclude that starvation-selected flies have not become as obese as possible, despite long-term directional selection favoring lipid storage. Supported by IOS-1355210 and DBI REU 1358896 from NSF and R15-GM100395 from NIGMS.

58-3 PAVLICEV, M; Cincinnati Children`s/University of Cincinnati; *mihaela.pavlicev@cchmc.org*
Menstruation and parturition: secondary serial homologa?
At the beginning of pregnancy, the females of most placental mammals undergo a specific transformation of the uterine lining, the endometrial decidualization, which accommodates the invasive implantation of the conceptus, and supports the fetus through the variably long pregnancy. This decidualization in most mammals requires the signal from conceptus- hence it occurs only in the case of fertilization. In primate females and a few other species (e.g., bats), decidualization has been assimilated into the spontaneous ovarian cycle, and occurs irrespective of the presence of conceptus. Thus primate maternal physiology spontaneously undergoes a transformation into a pregnancy-like state after every ovulation. This state ends with menstruation, the shedding of the decidualized endometrial lining, followed by the regeneration of uterus before new proliferation occurs. Interestingly, the processes involved in triggering menstrual shedding - the inflammatory cytokine profiles, prostaglandins, cramping- are highly similar to the processes triggering birth. We propose that the parturitive pathways have been coopted into menstrual cycle to shed decidualized endometrium. As birth of course is present in non-menstruating species, and thus predates spontaneous decidualization and menstruation, this serial homology is referred to as secondary. Such occurrence of pregnancy-like physiology in non-pregnant state offers a great asset for non-invasive research on human pregnancy and parturition.

P2-143 PAVLICK, C/R*; EMILY, B/R; ERIKA, M/J; RIVERA-FIGUEROA, V; SALAGUINTO, T/C; FERNANDEZ, A; HRANITZ, J/M ; GONZALEZ, V/H; PETANIDOU, T; TCHEULIN, T; BARTHELL, J/F; Bloomsburg University, Pennsylvania, University of Massachusetts, Amherst, Salem College, North Carolina , University of Puerto Rico Rio Piedras, Whitman College, Walla Walla, Washington, University of Baltimore, Maryland, University of Kanas, Lawrence, University of the Aegean, Mytilene, Greece, University of Central Oklahoma; *crp69850@huskies.bloomu.edu*
Removal of a Specialist Pollinator on Field Bindweed Reveals Competitive Release for a Generalist Pollinator
Field bindweed (*Convolvulus arvensis*) is an invasive weed, native to Europe and Asia, whose flowers reward diverse pollinators throughout midsummer. We examined foraging niche competition between two bee pollinators of *C. arvensis*, *Systropha curvicornis* (specialist) and *Lasioglossum malachurum* (generalist) in removal experiments on Lesvos, Greece. We recorded the natural visitation of these pollinators before and after removals. Before removal of bees, we measured natural visitation for one to three days. *S. curvicornis* and *L. malachurum* were removed in mass, each at a different site, for one day. We monitored the response one species to decreased presence of the opposing species over several days of visitation observations, as we continued removals so that catch per effort of each species increased at removal sites. At the site of *S. curvicornis* removal, the temporal foraging niche of *L. malachurum* was lengthened in response to reduced visitation by *S. curvicornis.* At the site *L. malachurum* was removed, the temporal foraging niche of *S. curvicornis* was unaffected by the removal of *L. malachurum*. The expanded foraging time by *L. malachurum* in the absence of *S. curvicornis* supports the hypothesis that these two pollinators display temporal niche partitioning on *C. arvensis*, wherein the generalist cedes time on *C. arvensis* to the specialist. These results are corroborated by our study of pollen loads extracted from *L. malachurum* at each site.

132-5 PAVLOV, V.*; ROSENTAL, B.; HANSEN, N.F.; BEERS, J.M.; PARISH, G.; ROWBOTHAM, I.; BLOCK, B.A.; Standord University, Monterey Bay Aquarium; *vpavlov@stanford.edu*
Hydraulic control of tuna fins: A hint for optimal engineering design
The lymphatic system in teleost fish has similar genetic and developmental origins to the mammalian lymphatic system, which is involved in immune response and fluid homeostasis. Here, we show that the lymphatic system of tunas functions in swimming hydrodynamics. Specifically, a musculo-vascular complex is involved in the hydraulic control of median fins for maintaining swimming stability. This specialization of the lymphatic system is associated with the scombrid fishes and may have evolved in response to the demand for stability control in these high-performance species. The unique feature of the musculo-vascular complex described here in tuna fins is that, unlike other known examples of animal hydraulics, it is formed by the integration of the lymphatic vessels and muscles having skeletal support. The complex is comprised of the three elements of a canonical hydraulic system: muscles that may serve as a hydraulic pump to pressure the lymphatic fluid, vascular vessels to guide and control the system, and fin rays acting as actuators to convert pressure energy into mechanical energy. The hydraulic system of tuna fins is similar to an engineer's design of the control surface. Tuna are of comparable size and speed to autonomous underwater robotic vehicles, which are currently used extensively worldwide to perform the wide range of ocean survey and inspection applications. The advantages of hydraulic force generation and transmission, as well as the ability to change dynamically their stability properties during transient motion by altering fin sweep, make this strategy a solution of choice for bio-inspired aquatic robotics.

P3-124 PAYNE, AA*; HORR, DM; JOHNSON, MA; Trinity University; *apayne2@trinity.edu*

Use It and Lose It? Behavioral and Energetic Costs of Lizard Tail Autotomy

The social displays of many species of lizards include tail movements, such as waving, curling, or lifting the tail. Tail displays can also be used to distract potential predators, which might attack the lizard's tail instead of its head or body, yet the loss of the tail may forfeit an important store of energy. In this study, we examined the relationship between lizard tail use and the frequency of tail autotomy. If the benefit of losing the tail in a predator encounter is outweighed by the social or energetic advantages the tail provides, we predicted that the rate of tail loss would decline. We studied five lizard species that vary in tail use: greater earless lizards (*Cophosaurus texanus*) and curly tail lizards (*Leiocephalus carinatus*) use tails frequently in display, Mediterranean house geckos (*Hemidactylus frenatus*) and crested anoles (*Anolis cristatellus*) use tails occasionally, and green anoles (*Anolis carolinensus*) almost never include tail movements in display. We observed lizards of each species in the field to quantify the use of the tail in social contexts, and performed predator simulation trials to quantify tail use in predatory contexts. We also approximated energetic content of the tail using the ratio of tail mass to body mass. We found that lizards that use their tail frequently in social contexts also use the tail frequently in predator encounters, and in most of the taxa studied, that frequent tail use may be associated with frequent tail loss. Further, we found no association between tail energy storage and autotomy. This study provides a framework for studying the ecological tradeoffs involved in maximizing long term success in the face of short-term predation risk.

S3-8 PÉREZ-MORENO, JL*; BALÁZS, G; BRACKEN-GRISSOM, HD; Florida International University - Biscayne Bay Campus, North Miami, FL, Eötvös Loránd University, Budapest, Hungary; *jpere645@fiu.edu*

Transcriptomic and epigenetic insights into the evolution of vision loss in cave-dweling crustaceans

The molecular mechanisms by which organisms adapt to their environments have long been sought to fully understand fundamental processes pertaining to organismal biology, ecology, and evolution. Animals that inhabit subterranean environments often undergo various distinct physiological, morphological, and behavioral modifications (referred to as "troglomorphy") as they transition to life in perpetual darkness. However, the molecular basis behind these troglomorphic changes in subterranean populations remains poorly understood. Important questions remain to be answered concerning the mechanisms involved in the loss of traits at the transcriptomic level, and the role of epigenetic modifications in driving evolution in these systems. In this study we investigate the transcriptional and epigenetic basis behind the reduction of vision in natural populations of cave crustaceans using a combined DNA methylation and RNA sequencing approach. To do so, we employ comparative phylogenetic, transcriptomic, and epigenetic methods on surface and cave-adapted natural populations of an emerging model cave species, the isopod *Asellus aquaticus*, and the amphipod *Niphargus hrabei*. By sequencing and assembling robust *de novo* transcriptomes and methylomes, we identified and characterized differentially methylated and expressed genes and pathways between surface and cave populations of the aforementioned species. With such, we aim to provide a solid bridge between genotype-phenotype, and improve our understanding of patterns of molecular evolution in extreme environments and their role in analogous systems.

P1-29 PEIXOTO, TL*; SUMMERS, AP; KOLMANN, MA; Univ. of Washington; *peixoto.t@husky.neu.edu*

Plates and Ridges: Form and function of armored scales in poachers (Agonidae)

Armor in animals can defend against predators and serve as support for animal movement. Poachers (Agonidae), nested within the cottoid fish lineage, are differentiated from other sculpins by their heavily-ossified dermal armor. They have elongate bodies entirely covered by bony plates ranging in morphology from unadorned to intricately ornamented. We used micro-computed tomography (μCT) scanning to characterize regional variation in armor plating along the body of *Agonopsis vulsa*, in adults and across ontogeny. In addition to gross morphology, we used CT-phantoms (hydroxyapatite standards of known density) to examine differences in mineralization of these bony plates. *A. vulsa* cross-sections show staggered series of eight bony plates that encircle and repeat along the length of the fish's body, forming eight longitudinal ridges. The arrangement and number of plates remains fixed throughout the individual's life. Excluding the head, these bony plates cover the majority of the body except for a small ventral area between the pelvic fins. Dorsal and longitudinal ridges do not show gross wear, but ventral plates do, and they have a more flattened morphology. Dorsolateral plates generally have ~45% of their total surface area overlapping with adjacent plates, with the majority of overlap on the antero-posterior plates of sequential segments. Initial estimates of density, based on brightness values, show that plate bases are less dense than plate tips, while plate estimated density show greater variation in the middle of the fish's body. By comparing *A. vulsa* with other poachers, we will discuss how the specific spacing and orientation of armor ‘tiles' shapes the dexterity, resilience, and ecology of armored species.

P1-211 PEKAR, KJ*; CULLER, ME; ONTHANK , KL; Walla Walla University; *katherine.pekar@wallawalla.edu*

Acidified Oceans and Octopuses: How Gene Expression in Octopus rubescens Changes in Elevated CO_2

Global anthropogenic increases in atmospheric carbon dioxide contribute to decreased marine pH. This process, known as ocean acidification, is predicted to increase ocean average carbon dioxide pressure from 400 µatm to 750 µatm and decrease ocean average pH from 8.1 to 7.8 by 2100. To better understand the response of octopuses to high CO_2 and low pH, we kept three *Octopus rubescens* in a controlled high CO_2 environment and three *O. rubescens* in a control CO_2 environment. After ten days, we excised gill tissue and used mRNA sequencing to determine differential gene expression between treatment and control octopuses. Using the DESeq2 package in R, differential expression analysis identified over 1,200 apparent differentially expressed genes (DEGs) between treatments over a multitude of pathways. Several DEGs indicate upregulation of anaerobic metabolic processes and downregulation of aerobic metabolic processes in elevated CO_2. In conjunction with previous research that found octopuses have higher ventilation rates and increased critical oxygen pressure in elevated CO_2, our findings suggest that octopuses in acidified water may be struggling to breathe.

P3-81 PELLICANO , A/J*; GAGLIO, A/E; LYNCH, K/S; Hofstra University, New York; *apelli4@pride.hofstra.edu*

Comparison of mechanisms underlying differences in multimodal courtship displays in two species of cowbirds

Two species of cowbirds are found within North America; the brown-headed cowbird (*Molothrus ater*) and the bronzed cowbird (*Molothrus aeneus*). The males of these species use multimodal courtship displays to attract females. However, the courtship display of the bronzed cowbird is a highly energetic display that is substantially costlier than the display of the male brown-head cowbird. Behavioral measurements reveal that the male bronzed cowbird performs ground and aerial hover displays for an average total duration of 5.4 seconds. While in the aerial hover display the male bronzed cowbird beats his wings an average of 9.8 beats/sec (n = 8) for an average of 5.4 (n = 8) seconds and performs this display an average of 0.6 meters (2 feet) off the ground. On the ground, before or after performing an air-display, the male bronzed cowbird will do a combination of behaviors entailing either lightly beating its wings, displaying its ruff, producing a single call, and/or displaying its full wingspan for an average total duration of 10.1 (n = 8) seconds. By contrast, the male brown-headed cowbird performs only ground displays for an average total duration of 1.6 (n = 8) seconds and beats its wings an average of 2 beats/sec (n = 8) for approximately 1.6 (n = 8) seconds. We are currently using scanning electron microscopy of wing features, quantitative PCR in pectoralis muscles and androgen hormone assays to examine the physiological and anatomical mechanisms that may underlie the evolution of this striking difference in courtship displays between two closely related cowbirds.

142-1 PENNEY, B.K.*; EHRESMANN, K.R.; JORDAN, K.J.; RUFO, G.; Saint Anselm College; *bpenney@anselm.edu*

A microcomputed tomographic investigation of spicule networks in dorid nudibranchs

Dorid nudibranchs (Gastropoda: Nudipleura) are a key taxon for studying the evolution and interaction of chemical defense, color patterns and feeding specialization, yet we lack a sufficiently detailed phylogeny for hypothesis testing. New morphological characters would clearly help. One possibility is the interior spicule networks of dorids, but we know little about their form or how they vary within or among species. However, studying these networks typically requires clearing and staining, thus limiting the specimens that institutions are willing to lend. We compared traditional staining methods vs micro-CT of specimens representing 10 species of *Aldisa*, *Cadlina* and *Onchidoris*. We found that micro-CT offered a non-destructive view of sufficient resolution to study the gross morphology of networks, although fine structures images were too grainy to allow robust comparisons. Network form did not vary within species and was consistent within genera. The three genera varied in several obvious characters, such as presence of a blood channel, large dorsal spicules, and multispicular tracts, as well as in relative size, shape and orientation of spicules. This suggests these networks will prove a fruitful source of genus-level characters within phylogenies.

3-8 PENROD, LM*; DADDINO, A; DIAMOND, K; JOHANSEN, JL; STEFFENSEN, JF; DOMENICI, P; Florida Institute of Technology, Univ. of San Francisco, Clemson Univ., UT Austin Marine Science Institute, Univ. of Copenhagen, IAMC-CNR Oristano; *lpenrod2011@my.fit.edu*

Take it or leave it. Fast-start modulation in the great sculpin Myoxocephalus polyacanthocephalus

Fast-start escape responses are used by fish when dealing with predatory threats that require a quick response with high velocity. Recent work on archerfish has suggested that the kinematics of a fast start towards a prey is similar to that of escape response from a threat. Here we test the hypothesis that untrained predatory fish would respond to a food item dropped in the water with an escape response away from it. However, after training (which allowed fish to recognize the stimulus as a food item) predatory fish would respond to a food stimulus dropped in the water by bursting towards it, with kinematics comparable to those of an escape response. Great sculpin (*Myoxocephalus polyacanthocephalus*) were trained to perform a fast-start attack on a food item and the kinematics were compared among (1) escape response of untrained fish from a food stimulus (perceived as a threat); (2) escape response of untrained fish from a strong mechanical stimulus; and (3) trained fish's attack on food stimulus. We found that untrained and trained sculpin had similar turning rates away from and towards the food stimulus, although the trained fish had longer latencies. Untrained fish showed a higher variability in trajectories when escaping from the threat than trained fish when aiming at the food and had higher variation in their turning velocities and post-response linear velocities. Our results suggest that, after training to recognize a food item, great sculpin can modify their reaction to it from an escape response to a feeding attack.

122-3 PEPPER, RE; University of Puget Sound; *rpepper@pugetsound.edu*

Dispersal of seeds from splash-cup plants

Splash cup plants disperse their seeds with the help of raindrops. The seeds sit in a small conical cup (a few millimeters across) and are ejected upon drop impact. The seeds are ejected at velocities up to five times the impact speed of the raindrop, and are dispersed up to 1 m away from the parent plant, which is only a few centimeters high. Previous work by Amador *et al.* investigating the mechanism of this remarkable dispersal predicted an optimum cup opening angle of around 30°, which matched reasonably well with both the opening angle of splash cup plant species found in nature and experiments measuring dispersal distance performed with 3D-printed splash cup models. Those experiments were done with off-center drop impacts on initially empty cups with no seeds. We discuss similar experiments for cups that are not initially empty, but rather contain seed mimics, water, or both seeds and water. For some of these realistic initial states results are strikingly different from empty cups. Connections to theory will also be discussed.

137-4 PEPPER, RE; University of Puget Sound;
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Motivating students to read the textbook before class
Many faculty in STEM courses assign textbook reading in advance of lecture, yet evidence shows few students actually read the textbook. Those students that do read often do so only after the material has been presented in class. Preparing for class by reading the textbook beforehand improves student learning and is particularly critical for classes that employ active engagement strategies. Here I present strategies I have used to successfully motivate my students to read the textbook before class in physics classes ranging from introductory algebra-based physics to advanced courses for physics majors. In the introductory course, I used pre-class reading quizzes, a common strategy that has been shown effective in previous studies, but one that is somewhat time-consuming to implement. In my more advanced courses I used reading reflections, which required considerably less time to implement. While it was typical for less than 25% of students to read the textbook before I implemented reading quizzes or reflections, after implementing these strategies 70-90% of students reported reading the textbook before class most of the time. Students also report finding both the readings themselves and the quizzes and reflections valuable for their learning. While I implemented these strategies in physics course, I believe they would transfer well to courses in other science disciplines, such as biology.

13-1 PERELMUTER, JT*; SISNEROS, JA; FORLANO, PM; CUNY Brooklyn College and Graduate Center, U of Washington, CUNY Brooklyn College; *jperelmuter@gradcenter.cuny.edu*
What does a Vocal Fish have to say about Dopamine in the Ear?
Efferent modulation of auditory encoding in the ear under natural conditions remains poorly understood. Studies in rodents report an inhibitory effect of dopamine (DA) in the cochlea, hypothesized to protect the ear from noise trauma. However, stimuli tested are louder and longer in duration than those likely to be encountered in the natural soundscape in which ears evolved. A biological function for DA in the inner ear in the context of natural behaviors remains to be demonstrated. Our work with the plainfin midshipman fish, *Porichthys notatus*, suggests DA modulation is important for acoustic communication in social and reproductive contexts. During the breeding season, nesting males produce a nocturnal hum-like vocalization which females use to locate males for spawning. Females undergo a hormonally regulated enhancement of peripheral auditory sensitivity that facilitates mate localization. Importantly, during the breeding season, DA innervation is reduced in the inner ear and increased in the cholinergic hindbrain nucleus projecting to the ear. A single forebrain nucleus sends DA to both the ear and the efferent hindbrain nucleus. Terminals form direct synapses in the hindbrain but not in the ear, suggesting paracrine release and the potential for DA to modulate hair cells directly. Application of DA and receptor-specific drugs during sound-evoked extracellular recordings from hair cells confirmed that DA increases auditory thresholds. The seasonal decrease of DA in the inner ear appears to serve as a release of inhibition, adaptively improving auditory sensitivity for mate localization. DA modulation of social-acoustic signals in the peripheral auditory system is a function which may be conserved in other vocal vertebrate species.

P3-221 PEREZ, JK*; COHEN, CS; Romberg Tiburon Center for Environmental Studies, Department of Biology, San Francisco State University ; *jeynap@gmail.com*
Phylogeographic Variation in Leptasterias Clades Relative to Sources of Estuarine Outflow
Oceanographic processes can affect patterns of genetic variation in marine biota. Large amounts of freshwater coastal outflow can create barriers to gene flow and act as a selective force. Direct developing species may be used to assess environmental influences on local populations because they tend to have lower gene flow and a higher potential for local differentiation. We examined the phylogeography of a direct-developing sea star, *Leptasterias*, in the San Juan Islands (SJI), WA to assess the potential effects of outflow from the Fraser River, one of the largest sources of coastal freshwater in the Pacific Northwest. Prior phylogenetic analysis of *Leptasterias* clades around the San Francisco Bay outflow, CA showed a pattern suggestive of selective forces on populations impacted by estuarine outflow, leading to our prediction that freshwater sources may have a strong effect on *Leptasterias* distribution. In the SJI, preliminary results of mitochondrial cytochrome oxidase 1 (CO1) barcoding (n=97) found three co-occurring clades of *Leptasterias*: *L. aequalis A*, *L. aequalis B*, and *L. hexactis*. The distribution of these CO1 clade distributions in the SJI suggests that *Leptasterias* patterns of variation could be related to proximity to plumes from the Fraser River ($\chi2$, $p<0.05$). Additionally, *L. aequalis A* and *B* clades from two *Leptasterias* complexes dominate populations in WA, while *L. aequalis K* and *clade Y* from the same respective complexes dominate populations in CA, indicating a latitudinal difference in clade composition. These results suggest that freshwater sources may influence spatial genetic variation among *Leptasterias* populations across regions.

P2-56 PEREZ, AC*; CHANDLER, CH; State University of New York at Oswego; *aperez@oswego.edu*
Determining the frequency of Wolbachia infections within three wild-caught terrestrial isopod species (Porcellio laevis, Porcellio scaber, and Trachelipus rathkei)
Wolbachia is a bacterial infection that is found within many arthropod species including: fruit flies, mosquitos, and terrestrial isopods. The effects of Wolbachia within an individual host can change its reproduction in significant ways. For example, in the presence of Wolbachia, an infected male isopod may develop functioning female sex organs, which leads to its sex transformation; this phenomenon is called feminization. Although feminization is the most common effect of Wolbachia observed in terrestrial isopods, other possible effects from this bacteria include: cytoplasmic incompatibility, male-killing, and parthenogenesis. In order to understand the influence that Wolbachia has on its host, the prevalence of Wolbachia within the experimental population must be measured. Polymerase chain reaction is utilized in order to detect the presence of Wolbachia within distinct terrestrial isopod species. In this study, the focus is on the prevalence of Wolbachia infections in the species: Porcellio laevis, Porcellio scaber, and Trachelipus rathkei from multiple locations throughout the United States. The results confirming this bacterial infection within these nonlocal isopods will allow new crosses to be established and observed, in the hopes of determining the effects of Wolbachia infection on these host species.

P1-148 PERISHO, EJ; Indiana State University; *eperisho@sycamores.indstate.edu*

Hoot's Who: A Morphological Comparison of Eastern and Western Barred Owl Populations

Traditionally, an eastern United States species, the barred owl, *Strix varia,* has been dispersing westward for the past seventy years, and arrived in northern California 30 years ago. *S. varia* is a large, aggressive, forest generalist and performs well in its new environment. It outcompetes its close relative, the threatened northern spotted owl (*Strix occidentalis caurina*) wherever the two species have overlapping ranges. Recent museum collections of western specimens of *S. varia* suggest that there may be morphological differences between western and eastern populations. These differences may be correlated to the advent of *S. varia* in California; the species could be adapting to new habitats, or receiving new genes through hybridization with *S. occidentalis caurina*. We investigated potential differences in size, coloration, and feather pattern between the several populations of barred owls in eastern and western USA and Mexico. For each individual, we measured wing chord, length of primaries, beak length and beak depth, and scored for color. The feather pattern of the stomach, which is subject to the most variation, was scored as well. Analyses showed that while there is no significant disparity of size between the east and west, the two populations do differ in color and belly pattern. The means of assessing color and pattern variance was by eye, but still yielded promising results. Future protocols using standardized means of color and pattern analysis, possibly through utilization of spectrophotometry and/or digital imaging, will add rigor to these analyses.

P2-252 PERKINS, H; HEITMANN, A*; ASPBURY, AS; GABOR, CR; Texas State University; *gabor@txstate.edu*

Synergistic effects of Roundup and corticosterone on antipredator responses of Incilius nebulifer tadpoles

Exposure to pesticides, especially in early life stages, may negatively impact amphibian populations. These effects may arise as a function of direct mortality of individuals, but indirect effects such as impacts on hormonal regulation of homeostasis or of other necessary survival traits, can also negatively impact populations. Corticosterone (CORT) is the main amphibian stress hormone, and elevations of CORT can interfere with antipredator responses. We examined the synergistic effects of an herbicide, Roundup (active ingredient = glyphosate), and exogenous CORT on tadpole growth, CORT and antipredator responses in *Incilius nebulifer*. We exposed tadpoles for 7 days to one of 4 treatments: exogenous CORT, Roundup, CORT plus Roundup, and control. We then measured water-borne CORT release rates and placed the tadpoles in fresh water, we then exposed tadpoles to dragonfly nymph predator diet cues. We measured tadpole activity before and after exposure to the predator cue, then measured water-borne CORT release rates of each tadpole. We found that tadpoles exposed to CORT or CORT plus Roundup had significantly higher CORT release rates prior to predator exposure than those in the other two treatments, but CORT after exposure to the predator cues did not differ across treatments. CORT release rates after exposure to predators were the same as the initial control treatment release rates. Tadpoles decreased activity in response to predator cues in all but the CORT plus Roundup treatments, and the tadpoles from the CORT plus Roundup treatments were also the least active overall. We conclude that there are synergistic effects of Roundup and CORT on the behavior and physiology of *Incilius nebulifer* tadpoles, indicating that more stressed tadpoles are less likely to survive predator attacks when exposed to the herbicide Roundup.

61-2 PERLMAN, BM*; POURESFANDIARI, P; DANKOVICH IV, LJ; AZIZI, E; Univ. of California, Irvine, Univ. of Maryland, College Park; *bperlman@uci.edu*

Does an anatomical latch amplify power during a frog jump?

To amplify power a number of invertebrates rely on anatomical latches that decouple the storage and release of elastic strain energy. To date, no anatomical latch has been found in vertebrates. However, frogs amplify power by using a dynamic shift in mechanical advantage (MA) that allows for slow storage and rapid release of elastic energy. We examine whether a fibrocartilage protrusion (lump) in the plantaris longus tendon can augment the storage and release of elastic energy by acting as a latch. If this structure were to function as a latch we predict tendon movement would be greater above vs. below the ankle joint when the frog leg was in a crouched position and the lump engaged. During leg extension and disengagement of the lump, the tendon would show similar displacement above and below the ankle joint. We isolated legs of bullfrogs (*Lithobates catesbeianus*) and secured the intact leg to a platform attached to a servomotor. The sciatic nerve was stimulated via a nerve cuff to elicit a contraction in the plantaris muscle. Trials were recorded at 500 fps and markers placed on the ankle joint and tendon were digitally tracked and analyzed. Results partially supported our hypothesis: the tendon moved more above vs. below the ankle joint. No difference was found in tendon movement when comparing the leg in a crouched position vs. extended, suggesting the lump did not act as a latch. The lump increased the muscle moment arm as it slid across the joint during ankle extension. The structure may augment an increase in effective MA during leg extension, a mechanism thought to be responsible for facilitating elastic energy storage and release in jumping frogs. Our results were confirmed by a physical model inspired by the frog leg where its anatomical and mechanical features could be broadly varied to further test our hypotheses.

113-6 PERRY, G*; BERGEY, C; JOHNSON, S; KOENIG, A; SULLIVAN, S; BOUFANA, B; CRAIG, P; CASTILLO, Y; MAHANTY, S; GARCIA, H; Penn State U., U. of Salford, U. Peruano Cayetano Heredia, U. Melbourne; *ghp3@psu.edu*

Human Tapeworm Functional and Evolutionary Genomic Adaptations to Cooking-Related Heat Stress

Tapeworms have a complex lifecycle that requires both definitive (carnivore) and intermediate (typically herbivore) hosts, with adult parasites developing in carnivore intestines following the consumption of herbivore tissues containing tapeworm cysts. Phylogenetic and evolutionary biology studies of tapeworms can provide valuable proxy insights into the history of definitive host carnivory and associated behavior. Three tapeworm species primarily parasitize humans: *Taenia solium* (secondary host: pigs), *T. asiatica* (pigs), and *T. saginata* (cattle). We are using an integrative functional and evolutionary genomics approach to test the hypothesis that these tapeworms may have evolved to withstand heat stresses associated with meat cooking, a uniquely human behavior. First, we heated *T. solium* cysts to temperatures from 37 to 56 ° C, followed by RNA sequencing to identify significantly differentially expressed genes. We also sequenced and assembled the genomes of 9 *Taenia* tapeworm species (including the three human taxa) to identify gene families with elevated duplication rates on the human lineages, and to intersect these results with those from the RNA-seq experiment. We identified genes differentially expressed under high temperature whose protein products are known to be involved in the heat stress response (e.g., heat shock 70 protein, q=4.2x10-16; universal stress protein, q=9.9x10-35; cytochrome c oxidase II, q=5.2x10-30). While our comparative genomic analyses are ongoing, we preliminarily observe significantly more heat shock protein gene copies in the genomes of the three human tapeworm species than in those of any other tapeworm.

P1-226 PERRY, A.*; JENT, D.; BLACKFORD, E.; TATE, A.T.; Vanderbilt University; *abby.perry@vanderbilt.edu*

The impact of eukaryotic microbiota on the dynamics of immune responses in flour beetles

Eugregarines are protozoan members of the microbiome present in a wide variety of insect hosts. Emerging evidence suggests that their presence can modulate the outcome of subsequent infection with other parasites, but it is still an open question as to whether gregarines interact with other microbes through competition for resources or through stimulating cross-reactive immune responses. In this study, we used qPCR to quantify variation in the immunological dynamics of lab and wild populations of flour beetles (*Tribolium castaneum* and *T. confusum*) after infection with the bacterium *Bacillus thuringiensis* (Bt), identifying a role for the Toll pathway in generating heterogeneity in antibacterial resistance among species and populations. We then investigated the impact of eugregarine co-infection on these dynamics. Our results suggest that gregarines alter the local immunological landscape within the gut, but that the reduction in bacterial growth rates in gregarine co-infected individuals is driven primarily by competition for energetic resources among parasites. This study reveals a role for eukaryotic members of the microbiome in modulating disease susceptibility phenotypes in natural populations, and gives new insight into patterns of natural variation in immunological dynamics among host life stages, populations, and species.

P2-158 PERRYMAN, DC*; PANDIT, MM; GRINDSTAFF, JL; Oklahoma State University, Oklahoma State University ; *danielle.perryman@okstate.edu*

Effects of Supplemental Feeding on Nesting Success of Eastern Bluebirds, Sialia sialis

A common anthropogenic influence on wildlife is the use of supplemental bird feeders. Dependent on abundance and natural food availability, this supplemental food source may influence survival and productivity. We experimentally manipulated supplemental food availability in a wild population of Eastern Bluebirds, *Sialia sialis*, to examine the influence of bird feeding on nesting success, especially when supplemental feeding is inconsistent. Adult and nestling bluebirds were assigned to one of three groups. In the first group, birds received mealworms throughout breeding. In the second group, birds received mealworms from nest completion until nestlings hatched. Birds in the third group received no supplementation but were disturbed at the same frequency. Nestling growth and nest success were then calculated. Finally to determine if differences in habitat quality contributed to the effect of food supplementation on nest success, data on invertebrate abundance were collected on a subset of territories. Nestling mass, tarsus, and wing chord length were not significantly affected by experimental treatment. Further, clutch size, hatching success, brood size, and fledging success were not significantly affected by treatment. Invertebrate abundance and richness were similar between years, across grass heights, as well as across nest box trails. Invertebrate abundance and richness were not correlated with nesting success metrics and did not statistically influence nesting success. Supplemental food availability may only have significant effects on nest success in years with low environmental food availability. Although we did not find direct benefits of supplemental feeding for bluebirds, bird feeding can be beneficial to the community, scientists and wildlife through engagement of the public in science.

65-5 PETERS, JM*; PELEG, O; MAHADEVAN, L; Harvard University; *jcbptrs@gmail.com*

Collective thermoregulation by morphing honeybee swarms

When honeybee colonies reproduce, about half of the workers (~10,000 bees) and a queen fly from the nest and form a cluster on a nearby tree branch. The swarm remains here for a period of hours to days while scouts search for suitable nest sites. The cluster of bees is exposed to fluctuating ambient temperatures and changes its collective morphology to maintain stable core temperature. Previous work has shown that the cluster reduces its surface area and porosity when exposed to cool temperatures to conserve heat. At high temperatures, the cluster expands to dump heat to the environment. However, little is known about the control and dynamics of this morphing process or how the cluster balances mechanical stability and thermal stability. We placed honeybee swarms in a temperature controlled room and exposed them to various rates of heating and cooling. We used a custom 3D scanner to reconstruct the shape of the swarm every few minutes during these temperature cycling trials. This allows us to accurately quantify how the swarm changes its volume, surface area, density and other morphological characteristics in response to finely controlled temperature fluctuations. Preliminary results suggest that the cluster uses different strategies when responding to rapid temperature fluctuations than it does in response to slow fluctuations. In addition, the cluster is able to contract more rapidly than it can expand. This rate-dependence and hysteresis is likely attributed to packing and unpacking dynamics and mechanical constraints associated with breaking and reforming linkages while supporting a load.

P3-52 PETERSHEIM, JI*; LLEWELLYN, HJ; SURMACZ, CA; HRANITZ, JM; Bloomsburg University; *csurmacz@bloomu.edu*

Motor Responses in Honey Bees are Impaired Following Exposure to Sublethal Doses of Imidacloprid

Global declines in honeybees (*Apis mellifera*) have been linked to Colony Collapse Disorder (CCD), a phenomenon that occurs when worker bees disappear from the colony, leaving the brood unattended. While there is no single cause of CCD, sublethal doses of pesticides cause physiological and behavioral changes that adversely affect hive health. This research aims to determine: 1. if motor functions of bees are impaired after treatment with sublethal doses of imidacloprid, and 2. if dose-response curves differ in bees collected in early summer vs. late summer. Honeybee foragers collected from apiaries in central PA were harnessed, fed to satiation, and after 22-24 hours, randomly assigned to control or various treatment groups. Control bees were fed 10 µl of 1.5 M sucrose. Bees in treatment groups were fed with imidacloprid (Macho®4.0, AgriStar) at doses of 1/5th,1/10th,1/20th, 1/50th,1/100th, or 1/500th of the LD_{50} (18 ng/bee). Four hours post-treatment, motor tests were conducted: abdomen and leg movement, antennae movement, and proboscis extension reflex. Scores of 0 (no function), 1 (impaired function), and 2 (full function) were assigned. A logistic regression model showed an effect of imidacloprid on motor responses. While the dose-response curves differed between bees collected in early summer vs. late summer, motor responses of bees were consistently impaired at 1.8 and 3.6 ng/bee in early and late summer bees. These results suggest that sublethal doses of imidacloprid in the range that bees are exposed to in the field impair motor function, a factor that may negatively affect hive health. Bees collected in early summer showed a greater frequency of impairment at higher doses of imidacloprid when exposure to local agrichemicals was likely to be high.

25-1 PEYLA, JF*; SENFT, SL; HANLON, RT; College of Charleston, SC, Marine Biological Laboratory, Woods Hole, MA; *peylajf@g.cofc.edu*

Secrets to Squid Chromatophore Colors: Unexpected Relationships Between Pigment Granule Color and Morphology with Implications for Biophotonics

A defining morphological characteristic of coleoid cephalopods is skin embedded with an array of chromatophores: dynamic, colored neuromuscular organs. At the core of each chromatophore is an expandable sacculus of numerous minute granules containing ommochrome pigments. We have found using electron microscopy and quantitative image analysis that each color class of *Doryteuthis pealeii* chromatophore contains distinct assemblages of granules with characteristic size, shape, and external rugosity: brown granules are large, ellipsoidal, and smooth; reds are mid-sized and ring-shaped or grooved; yellows are small, spherical, and fine-grained. The distinctive internal and external morphologies of the granule color classes suggest structural coloration mechanisms that may complement the pigmentary mechanisms for coherent and efficient color production from each color class of chromatophore. Future modeling of these biophotonic interactions is now possible with these new data. This work was funded by AFOSR grant A9550-09-0346 to RTH and NSF-REU grant DBI-1359230 to MBL. We would like to thank Karen Crawford, Kyle Fisk, Kyle Ford, Richard Gates, Kasia Hammar, Louis Kerr, James Kutlowski, Alan Kuzirian, and Lydia Mäthger.

20-1 PHILLIPS, MB *; AMEMIYA, CT; Univ. of Washington, Univ. of California, Merced; *m.philli.50@gmail.com*

Chitin Within the Electrosensory Organs of Cartilaginous Fishes

Chitin is the second most abundant biopolymer on earth and is a major component of rigid biological structures such as the outer cuticle of arthropods (i.e. crabs and lobsters) and fungal cell walls. The molecule is produced by a myriad of organisms using a biosynthetic pathway involving enzymes called chitin synthases. Since the discovery of chitin, it had been widely assumed that vertebrates do not produce the polymer themselves. Recently, however, our lab discovered chitin synthase genes within a variety of vertebrates and identified chitin in many places from the gut lumen of zebrafish to the epidermis of both fishes and salamanders. In our ongoing investigations into vertebrate chitin, we unexpectedly discovered chitin within the electrosensory organs (known as ampullae of Lorenzini or AoL), of cartilaginous fish (chondrichthyans). All living organisms emit weak electric fields and chondrichthyans, such as sharks and rays, use their AoL to detect these fields in order to orient towards potential prey or mates. A single AoL consists of a tubular canal that on one side opens to the environment *via* a pore in the epidermis and terminates in a spherical structure made up of specialized electrosensory cells that are responsible for signal detection. We show that chitin is present within the viscous hydrogel which fills the whole tubular AoL of several evolutionarily distant Chondrichthyan species. In one species, we have identified the sequences of two chitin synthase genes and observed the localized expression of one of these genes to embryonic AoL. These data provide further evidence for the endogenous production of chitin by many types of vertebrates and characterize chitin's presence in yet another distinct anatomical system. It remains to be studied how chitin contributes to the development and/or function of the chondrichthyan electrosensory system.

126-3 PHILSON, CS*; FILIPOWICZ, JP; FOLTZ, SL; RAY, A; DAVIS, JE; Radford University; *cphilson@radford.edu*

The PASSER Project: Using Microcomputer-Integration to Conduct Detailed Studies of Behavior-Environment Interactions

Integrating microcomputing into ecobehavioral field research provides a novel mechanism for the collection of detailed multi-modal data sets. Though this requires a substantial investment of time and technical ability, it offers the benefit of long-term, relatively low-cost, minimally invasive data collection with limited person-hour investments. Here we describe the development and initial results of the Programmable Automated System for Songbird Ecological Research (PASSER) Project, and its application to the study of songbird feeding behaviors in Radford, Virginia and primate feeding behaviors in the Madre de Dios Region of the Peruvian Amazon. In their simplest practice, PASSER feeders allow automated data collection of feeding activity, alongside a variety of environmental metrics (i.e. Photos or video, temperature, humidity and time). This allows us to conduct both rapid and long-term surveys of species diversity, as well as studies of behavior-environment interactions for those species. In Virginia, these feeders have shown how the changing seasons affect bird feeding patterns, and how variable environmental conditions further impact these behaviors, both within and across species. Similar feeders were also tested in the Peruvian Amazon, for a 2 week span, targeting local primate species. These feeders saw low primate activity, however the most activity was seen in the unit active for the longest time, showing that extending the active time of these feeders will yield activity. Second-generation PASSER feeders also provide the ability to interface with focal species. With the use of a touchscreen, speakers, and food delivery control, we are able to dynamically display a variety of stimuli, and to mediate direct interaction between subjects and the system. We discuss ongoing implementations and future directions for this type of work.

40-6 PICCIANI, N*; KERLIN, JR; SIERRA, NW; RAMIREZ, DM; SWAFFORD, AJ; CANNON, JT; JONDELIUS, U; PLACHETZKI, DC; DALY, M; OAKLEY, TH; University of California, Santa Barbara, Stockholm University, University of New Hampshire, Ohio State University; *natasha.picciani@gmail.com*

Prolific origination of eyes in Cnidaria with co-option of non-visual opsins

Animal eyes are morphologically diverse, variably complex, and essential for understanding the evolution of complex biological traits. While eyes evolved many times in bilaterian animals with elaborate nervous systems, image-forming and simpler eyes also exist in cnidarians, ancient non-bilaterians with simple nerve nets and neural condensations to process information. How often eyes of varying complexity, including image-forming eyes, arose in animals with such simple neural circuitry remains obscure. Here, we couple large-scale phylogenies of Cnidaria and their photosensitive proteins with a compilation of a vast literature on eyes and light sensing behavior to show cnidarian eyes originated at least eight times, with complex lensed-eyes having a history separate from the others. Our experiments show widespread light sensing behavior in eyeless cnidarians and comparative analyses support ancestors without eyes that already sensed light with dispersed photoreceptor cells. The history of expression of the photoreceptive protein opsin demonstrates distinct eye origins involved separate co-option of non-visual opsins into eyes. Overall, our results show eyes evolved repeatedly from ancestral photoreceptor cells in non-bilaterian animals with simple nervous systems, co-opting existing precursors similarly to what occurred in Bilateria. Our study underscores the potential for multiple distinct visual systems and underlying developmental pathways even in animals with simple nervous systems.

P1-157 PIPES, B.L.*; CORNWELL, A.L.; NISHIGUCHI, M.K.; New Mexico State University; *brian.pipes@gmail.com*
Squid light organ pH influences bacterial composition in the Euprymna-Vibrio fischeri beneficial symbiosis
The bioluminescent marine bacterium *Vibrio fischeri* has been used to study mechanisms of environmental specificity in mutualistic associations with animal hosts. *V. fischeri* colonizes the interior of the light organ of sepiolid squids (Cephalopoda: Sepiolidae) and produces luciferase based light which provides ventral counter-shading camouflage for the squid. Stressful conditions, such as low O_2 and pH levels may develop within the colonized light organ as a result of *V. fischeri* growth. Thus, beneficial adaptations to such stressful conditions may provide *V. fischeri* a competitive advantage in colonizing the light organ. We are investigating the feasibility of assaying the pH within the colonized light organ of the Hawaiian bobtail squid, *Euprymna scolopes* in order to determine if *V. fischeri* is adapted to thrive in a low pH environment. We have developed a series of plasmids containing pH sensitive green fluorescent protein (pH-GFP) derivatives, which, when expressed by *V. fischeri* colonizing the light organ, will produce an emission spectrum wavelength profile that correlates with pH, both within *V. fischeri* and in the lumen of the light organ. The use of pH-GFP expressing *V. fischeri* as a novel bioassay will allow us to determine whether pH is a determining factor in establishing a successful colonization by *V. fischeri* in sepiolid squids.

106-7 PLACE, NJ*; BRIEÑO-ENRIQUEZ, MA; COHEN, PE; SINOPOLI, JT; ALBERTINI, DF; LAIRD, DJ; HOLMES, MM; Cornell University, Center for Human Reproduction, Univ. of California, San Francisco, Univ. of Toronto, Mississauga; *njp27@cornell.edu*
Do Oocyte-Stem Cells Contribute to Protracted Fertility in Naked Mole-Rats?
In mammals, the discourse over the existence and functionality of oocyte-stem cells (OSCs) within the postnatal ovary is well into its second decade, with the vast majority of studies on both sides of the debate limited to few species exhibiting variant reproductive strategies. Owing to their exceptionally long reproductive lifespan relative to body size, we hypothesized that the naked mole rat (NMR, *Heterocephalus glaber*) might maintain continuous renewal of oocytes through OSCs. Our initial investigations have provided some support for this hypothesis. We found a substantial number of germ cells within postnatal NMR ovaries that were immuno-reactive for the pluripotency markers OCT4 and SOX2. In addition, germ cells marked by DDX4 (VASA) demonstrated evidence for recent mitotic activity, either by their co-labeling with phospho-histone H3 or by incorporation of the thymidine analog EdU. Chromosome spreads from NMR ovaries at postnatal day 28 (P28) revealed oocytes in all stages of prophase I, which coexist with cells that expressed markers of pluripotency. In contrast to mice, for which follicle formation is complete by P5, the breakdown of germ cell cysts and formation of primordial follicles are markedly delayed in NMRs. Whereas the ovarian reserve of follicles is nearly exhausted by a year of age in mice, we have observed an abundance of primordial follicles in the ovaries of a 10-year-old NMR. Ongoing research will determine how the NMR establishes its unusually large ovarian reserve and maintains it over an exceptionally long reproductive lifespan, including experiments to test whether OSCs in the postnatal ovary contribute to the NMR's protracted fertility.

P2-87 PLASMAN, M; MCCUE, MD*; REYNOSO, VH; TERBLANCHE, JS; CLUSELLA-TRULLAS, S; Stellenbosch University, South Africa and Universidad Autónoma de Tlaxcala, Mexico, St. Mary's University, Texas, Universidad Nacional Autónoma de México, Mexico, Stellenbosch University, South Africa; *melissaplasman@hotmail.com*
Temperature alters Digestive Energetics and Fuel Selection in a Lizard
Food provides animals with energy and other resources, yet processing an ingested meal also requires energy, this is called specific dynamic action (SDA). SDA is (at least partially) fuelled by oxidation of the recently ingested nutrients. In ectotherms, environmental temperatures can affect SDA and possibly fuel selection. We examined SDA, gut passage time, assimilation efficiency, and fuel use in the lizard *Agama atra* digesting crickets whose body lipids or proteins were isotopically labelled with ^{13}C. Lizards were tested at three ecologically relevant temperatures (20, 25, and 32ºC). We found that at higher temperatures the magnitude of the peak in a postprandial metabolic rate increased, while duration of the SDA response and gut passage time decreased. The oxidation of dietary protein peaked earlier than that of lipids at all temperatures tested. After the peak, protein oxidation rapidly decreased. Lipid oxidation, however, remained relatively high and stable for the duration of the trial at 20 and 25ºC and only decreased, but slowly, at 32ºC trials. These results indicate that in this lizard temperature has a pronounced effect on digestive energetics and that this effect differs between nutrient classes. Changes in environmental temperatures may thus alter the energy budget and nutrient reserves of these animals.

P1-210 PLATT, S*; WOLEK, MJ; LOVETT, DL; The College of New Jersey, Ewing; *lovett@tcnj.edu*
Hypo-Osmotic Increases in Hemolymph Levels of Methyl Farnesoate Correlate with Expression Profiles of Farnesoic Acid O-Methyltransferase in the Green Crab Carcinus maenas
Previous studies have demonstrated that hemolymph levels of methyl farnesoate (MF) in the green crab *Carcinus maenas* increased in response to exposure to dilute (< 27 ppt salinity) seawater (Lovett et al., 2001, 2006). Furthermore, the increase in MF levels did not commence until 8 hr after initial exposure to dilute seawater and acclimation levels of MF were attained within 24-48 hr after exposure. To understand the mechanism by which hemolymph levels of MF increase, the present study examined the effect of hypo-osmotic stress on relative transcript levels for farnesoic acid O-methyltransferase (FAOMeT), the terminal enzyme in the MF synthesis pathway. For crabs acclimated to dilute seawater, transcript levels of FAOMeT in the mandibular organs were higher than those of crabs acclimated to 28 ppt salinity seawater. Other crabs acclimated to 28 ppt salinity were transferred acutely to dilute seawater. In these crabs, transcript levels reached peak values 8 hr after transfer, increasing by almost three-fold from values at t=0. Transcript levels then decreased and by t=48 hr after transfer were not significantly different from those in crabs acclimated to dilute seawater. The timing of peak transcript levels in crabs acutely exposed to dilute seawater corresponds with the observed 8-hr lag in hypo-osmotic increases in hemolymph levels of MF. Hemolymph levels of MF appear to be regulated, at least in part, at the transcriptional level.

P1-260 PLECNIK, MM*; NAIK, S; VAN DOMELEN, R; RUOPP, R; FULL, RJ; Univ. of California, Berkeley; *mplecnik@berkeley.edu*
Role of Geometric Constraints on Reachable Workspace of Insect Limbs
Multiple, long limbs of arthropods can permit larger workspaces to find secure footholds and result in greater step lengths for rapid locomotion, if geometry does not constrain their trajectories. We defined a limb's workspace as a 3D volume that represents all possible footholds relative to the animal's body. We captured the morphology of the mid and hind limbs of cockroaches, *Blaberus discoidalis*, using photogrammetry and optical measures of joint range of motion. We modelled limbs as serial kinematic chains. The mid and hind workspace volumes extended the body volume space by 220 and 510 %, respectively, with a 16% intersection among leg workspace volumes. We parsed workspaces by decomposing them into step lines, segments of possible footholds parallel to the body axis that represent possible step lengths. We examined the potential trade-off of a secure foothold using a follow-the-leader (FTL) gait versus the maximum possible step length for high speed. A FTL gait requires that the posterior leg step within a possible secure foothold of the next anterior ipsilateral leg. For a fixed body pitch, an alternating tripod gait on level ground requires mid and hind step lines to be coplanar. For a follow-the-leader gait, step lines must additionally be collinear and possess a region of overlap. Surprisingly, when we searched for the longest collinear mid/hind step line pairs (top 5% at 15.1mm±6.7mm S.D.), we found an average overlap of 8.5mm. Moreover, the maximum collinear step length (25.6mm) was consistent with the maximum step length measured at maximum speed running (25 mm). Our model is a first step toward the creation of a structure-function design space for arthropod legs to reveal general design principles.

P1-173 PODOLSKY, ROBERT; CONRAD, HAILEY*; College of Charleston, Rutgers University; *hmc87@scarletmail.rutgers.edu*
Genetic Variation in Resistance to Ocean Acidification in Larval Development within a Northern Population of Arbacia punctulata
Ocean acidification reduces the level of calcite saturation in the water column, making it more difficult for pluteus larvae of *Arbacia punctulata* to lengthen the ciliated arms they use to suspension feed. A reduction in skeletal size could negatively impact larval growth as well as adult size and reproductive success. Adults from a population near from Woods Hole, Massachusetts were crossbred in a 3x3 mating design with sibships reared under either current CO_2 or 2.5x current CO_2. Larval skeletal measurements were used to estimate genetic variation for resistance to elevated CO_2. Larvae subjected to higher CO_2 exhibited less skeletal growth overall, particularly in the post oral arm rods, and also demonstrated increased asymmetry. Significant genetic variation was estimated for differences in post oral arm length between low and high CO_2. These results indicate that near-future ocean acidification could negatively impact *A. punctulata* larval growth and development, but that populations may have the capacity for an evolutionary response to increasing CO_2. Future studies will need to examine responses of genetically distinct populations of *A. punctulata* along its latitudinal range.

62-6 POLLOCK, NB; JOHN-ALDER, HB*; Univ of Texas Arlington, Rutgers University; *henry.john-alder@rutgers.edu*
Sex- and age-specific ectoparasitism in eastern fence lizards (Sceloporus undulatus): individual consistency and effects of season
Parasites and hosts form strongly interactive ecological bonds. Parasites extract matter and energy from their hosts and impose fitness costs on reproduction and survival. Previous reports on diverse species indicate that males are often more susceptible than females to ectoparasitism and that testosterone (T) may cause this sex bias. Furthermore, ectoparasitism among individuals typically varies substantially, suggesting that some individuals may consistently be more heavily parasitized than others. Thus, selection pressures imposed by ectoparasites may be sex-biased, and stronger on some individuals than others. We investigated seasonality, sex/age-specificity, and individual consistency of chigger mite loads (*Eutrombicula alfreddugesi*) on eastern fence lizards (*Sceloporus undulatus*) in the New Jersey pine barrens. Regardless of sex and age, mite loads exhibited seasonal variation associated with mean monthly temperature. Mite load increased in all age/sex classes from early June to mid-July, but the rank-order of mite loads was highly consistent among individual lizards. Mites were rare in the environment and on lizards during the breeding season, and adult males were not more heavily parasitized than females at this time. Mite loads were higher on yearlings than adults, higher on post-breeding adult females than males in early summer (when T is low in adult males), and higher on yearling males than females in mid- to late summer (when T is high in yearling males). These results suggest that costs and selection imposed by mites may differ systematically among individuals as well as between age/sex classes. The results only partially support the hypothesis that T causes male-biased mite-parasitism of lizards.

66-3 POORBOY, D.M.*; BOWERS, E.K.; BOWDEN, R.M.; SAKALUK, S.K.; THOMPSON, C.F.; Illinois State University, University of Memphis; *Dpoorbo@ilstu.edu*
Effects of territory quality on reproductive allocation in female house wrens (Troglodytes aedon)
In territorial birds, both parental and territory quality vary and influence resource allocation to offspring. In our study population of house wrens, evidence of such heterogeneity, its temporal consistency, and its fitness consequences, comes from the historic record of reproductive success at fixed-site nestboxes. To assess the potential effects of habitat heterogeneity independent of parental quality, we tested the hypothesis that territory quality influences female reproductive allocation in house wrens. Territories were categorized into low-, intermediate-, and high-quality based on fledging success the previous 5 years. Entrance size was increased in nestboxes (wrens prefer small entrances) on high-quality territories and on randomly-selected intermediate-quality territories to alter site attractiveness, thereby disrupting any covariation between territory quality and individual quality. Eggs were measured and cross-fostered in pairings between nests on high- or low-quality territories and intermediate-quality territories, to disentangle prenatal and postnatal effects of variation in territory quality. We found that territory quality had minimal effect on measures of parental resource allocation both prenatally and postnatally; however, a strong relationship between current nest success and territory quality persisted. Therefore, other factors of territory quality, such as predation risk, play important roles in determining reproductive success.

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Divergent designs: mechanical and anatomical variation along the vertebral column of two species of "dogfish" shark

In sharks, the vertebral column is engaged as a spring: both intervertebral joints and centra strain significantly during bending. The vertebral column has nonlinear mechanical properties, allowing it to function as a spring or a brake depending on the kinematic inputs to the system. These findings were isolated to specific regions of the vertebral column in a single species. Here we examine the dynamic mechanical properties along the length of the body, and we examine the histological morphology in two superficially similar but phylogenetically distant, shark species, the spiny dogfish, *Squalus acanthias*, and the smooth dogfish, *Mustelus canis*. We tested fresh segments of centra in bending over a range of frequencies and curvatures, similar to those experienced by these species when swimming. E' and E" (the elastic and viscous components of stiffness; respectively) were significantly stiffer in the caudal region than the precaudal, while *S. acanthias* was stiffer than *M. canis*. Second moment of area (I, a structural predictor of stiffness) was also greater in the precaudal region. However, work to bend (W, elastic energy) did not vary in either species. The morphology of the vertebral column varied among species dramatically. *iS. acanthias* had an open intracentral canal while the canal was closed in *M. canis*. *S. acanthias* central cartilage was a deep spindle shape and had long intervertebral joints compared to the shallow spindle and shorter joints of *iM. canis*. These data suggest that the caudal region, compared to the precaudal region, stores and releases more elastic spring energy during swimming. Since this pattern occurs in two phylogenetically distant species, these regional differences in vertebral column mechanics and functional morphology may be a general solution for thrust production in sharks.

S3-1 PORTER, ML; University of Hawai'i at Mānoa; *mlporter@hawaii.edu*

Eye reduction and loss - patterns across species and habitats

Eyes are reduced or lost across many species, representing most of the major animal lineages that have eyes capable of spatial resolution. Eye reduction and loss are generally associated with the decreased, or completely absent, levels of light associated with particular lifestyles (e.g. fossorial, parasitic) or habitats (e.g. deep-sea, subterranean). Because of the repeated occurrence across animal diversity, I consider whether there are commonalities in the proximate and ultimate processes leading to eye reduction and loss across species related to light level, habitat, or lifestyle. To attempt to address this question, I have surveyed literature on species with reduced or absent eyes in order to compare the anatomical and molecular underpinnings, as well as considered available RNAseq data to compare patterns in how both morphology and the expression of phototransduction molecules change towards a synthetic view of pattern and process in animal eye loss. Based on initial surveys, reduced light environments can lead to either reduced or expanded eyes, with commonality across species in the reduction of the numbers of expressed opsin genes, which code for the proteins involved in light detection. In contrast, habitats with no light seem to harbor animals where tissues still express opsins, albeit at reduced levels, despite the loss of the anatomical structures (e.g. photoreceptors, lens, neural pathways) required for vision. In both dim and no-light habitats, animals commonly express opsins associated with photoreceptors that are no longer present.

96-2 PORTER, M.L; STECK, M*; RONCALLI, V; LENZ, P; University of Hawaii at Manoa, Pacific Biosciences Research Center, Pacific Biosciences Research Center; *steck4@hawaii.edu*

Molecular Characterization of Copepod Phototransduction

Unlike other crustaceans, copepods lack compound eyes, depending on a frontal (nauplius) eye for vision. While naupliar eye photoreceptors have been characterized morphologically, little is known about the phototransduction cascade of this type of eye. Here, transcriptomics were used to identify candidate opsins in twelve taxonomically diverse copepod species. Within this high diversity of opsins, two major clades were observed in all species investigated: r-type middle wavelength sensitive opsins, and c-type pteropsins. There is additional evidence from a few species for the expression of several other types of opsins; long-wavelength sensitive r-type (harpacticoids only), tetraopsins, Rh7 opsins, and arthropsins. Several of these opsin types may be extraocular, including the pteropsins and tetraopsins, while the r-type middle- and long-wavelength sensitive opsins are likely used in the naupliar eyes. Main components for the visual pathway of the phototransduction cascade were also identified, including trp channels, arrestins, Gqα subunits, phospholipase C, and protein kinases. The copepod *Calanus finmarchicus* was observed to have ontogenic shifts in dominant opsin expression between naupliar and copepodite stages. The transcripts identified here provide a set of target genes for an analysis of the evolution of visual pigments present in the naupliar eyes copepods.

P1-30 POS, KM*; KOLMANN, MA; GIDMARK, NJ; Knox College, University of Washington, Friday Harbor Laboratories; *kmpos@knox.edu*

A comparative investigation of evolutionary history versus dietary niche in shaping pharyngeal jaw skeletal structure in cyprinid fishes

Minnows (Family Cyprinidae) are a trophically diverse clade, with species that specialize on myriad prey: shearing plants, crushing snails, chewing insects or sifting detritus. These diverse prey types make minnows a phenomenal model system for studying the interplay between diet and evolutionary history in shaping anatomy. However, the anatomy of this family has only been marginally investigated in published literature (only 3% of species have been imaged); even this sample size has shown that trophic anatomy of the pharyngeal jaws is strongly correlated to their diet specialization. Here, we used micro-computed tomographic imaging of 315 species of North American minnows (over 98% of species diversity) to evaluate how anatomical specialization, evolutionary history, and dietary ecology have shaped trophic diversity in this clade. Preliminary results show high rates of trophic convergence among genera (i.e. many overlapping trophic guilds), and we observed immense variation in morphology of several aspects: 1) muscle attachment area (a proxy for muscle force); 2) relative size of the ligament spanning left and right hemi-mandibles (a proxy for range of motion and skeletal flexibility); and 3) tooth robustness (a proxy for biting force application). For example, herbivorous and durophagous species show large muscle attachment areas and robust ligaments in contrast to lean, thin-ligamented jaws seen in insectivores. Interestingly, this variation is less prominent within closely-related species, suggesting that phylogenetic history is important. These trends show that convergence is widespread among minnow dietary guilds, and relatively small changes in skeletal anatomy between congeners accompany large shifts in diet.

P3-58 POUV, AK*; OHANIAN, A; PACE, DA; California State University. Long Beach; *akpouv@hotmail.com*

Using the Aerobic Enzyme, Citrate Synthase, to Understand Biogeographic Dispersal Potential in Echinoid Larvae

Temperature is a primary determinant of biogeographic distribution in animals due to its influence on biochemical processes. This study explores the possibility that habitat ranges of adult echinoids are linked to temperature sensitivity of metabolic enzymes during the planktotrophic larval stage. The *in vitro* thermal performance of the regulatory Krebs cycle enzyme, citrate synthase (CS), was determined in several echinoid larvae with the following thermal habitat ranges: *Dendraster excentricus* (2-28°C), *Strongylocentrotus purpuratus* (2-24°C), and *Strongylocentrotus fragilis* (0-10°C). Temperature sensitivity, ranging from 5-35°C, was assessed through Q_{10} calculations and Arrhenius breakpoint analysis. Q_{10} analysis showed that *D. excentricus* was the most temperature sensitive. *S. fragilis* exhibited a peak temperature sensitivity at 15-20°C and *S. purpuratus* was relatively insensitive to temperature except at the coldest extreme. *D. excentricus* did not exhibit any discrete change in activation energy throughout the temperature range, in concordance with its broad habitat temperature range. *S. fragilis* and *S. purpuratus* displayed discrete shifts in activation energy at 15°C and 20°C, respectively, matching their relative differences in habitat temperature ranges. The results of this study help to understand how thermal dependence of early life-history metabolic pathways has ramifications for dispersal potential of planktotrophic larvae of benthic marine organisms. This information is important for understanding biogeographic distributions and population dynamics of marine organisms.

P1-70 POWELL, MD*; HERMAN, R; RAY, A; HUDLIN, C; DAVIS, JE; Radford University; *mpowell48@radford.edu*

Comparisons of the decay rate of infrasound across gradients of anthropogenic disturbance and physical obstruction

Infrasonic communication is relatively understudied in the fields of wireless communication and bioacoustics. The most common methods of wireless communication employ electromagnetic signals, but electromagnetic interference can limit or block the effectiveness of these signals. Though several species have been shown to utilize infrasound for long distance communication, potential sources of active and passive interference are particularly understudied, in part due to the difficulty of producing and measuring infrasound. We hypothesize that infrasound is modulated both by the composition and density of the surroundings, whether natural or anthropogenic, as well as the relative size and distribution of intervening structures. This has significant implications for habitat fragmentation and communication across urban and rural environments. Here we discuss the decay rate of infrasound signals from tests run in natural environments including open fields, deciduous woodlands, and natural rivers in contrast to urban environments such as manicured lawns, enclosed alleyways, and suburban backyards. Infrasonic tones were generated in multiple settings and trials using a custom speaker design. The speaker output was measured by an electret microphone circuit for a constant amount of time. The outputs were recorded at multiple distances from the speaker, and Fourier Transforms of the results were used to calculate the measured intensities at those distances. Additional modulatory factors such as temperature, humidity, and wind speed were collected to control for and compare their effects across trials. The results of these studies will be presented as intensity vs distance graphs, from which the distance- and setting-dependent decay rate equations will be calculated.

64-1 POWERS, AK*; KAPLAN, SA; BOGGS, TE; GROSS, JB; Univ. of Cincinnati, Northeast Ohio Medical School; *krutzlaa@mail.uc.edu*

Two unusual mechanisms explain cranial bone fragmentation in cavefish

Astyanax mexicanus cavefish have undergone dramatic morphological changes, relative to their closely-related surface-dwelling relatives, including the loss of eyes and pigmentation. Adult cavefish also harbor cranial malformations, particularly in the suborbital series of bones surrounding the collapsed eye orbit. For example, in cavefish the third and largest suborbital bone (SO3) is fragmented into as many as 10 distinct bony elements. To shed light on the developmental basis of SO3 fragmentation, we performed a longitudinal, intra-individual staining and visualization procedure in live fish. We compared normal SO3 bone growth in surface fish with aberrant growth in cavefish from the onset of ossification through mature bone development. Surface fish SO3 bones form from a single ossification center directly inferior to the eye that expanded uniformly in an antero-posterior direction. In contrast, cavefish demonstrated multiple, secondary ossification centers arising spontaneously throughout development. Some of the ectopic ossification centers resulted in distinct fragments, but less frequently (~13% of the time) they were resorbed into the larger bony element. Interestingly, in cavefish a later post-ossification remodeling mechanism (mediated by osteoclast activity) led to the appearance of "channels" in the bony matrix resulting in fragmented bones. This second mechanism accounted for 90% of fragmented SO3 bones in cavefish. In sum, surface fish display typical patterns of SO3 bone growth, while two distinct ossification processes underlie fragmentation in cavefish. This work reveals dynamic changes to the cranial complex in cavefish, which arose in response to the extreme pressures of the cave environment.

93-1 POWERS, DR*; BLOOMQUIST, ER; TOBALSKE, BW; George Fox University, Newberg, OR, University of Montana, Missoula, MT; *dpowers@georgefox.edu*

Budgeting Body Heat by Hummingbirds during Hovering at Moderately High Temperature

Flying hummingbirds generate large amounts of endogenous heat due to the mechanical inefficiency of their flight muscles. Feathers must lie flat during flight to minimize drag, restricting heat dissipation to specific heat dissipation areas (HDAs) around the eyes, shoulders, and feet. When temperature is moderate (23°C), excess heat can be dissipated passively through HDAs to maintain heat balance. However, when temperatures become high, passive heat dissipation is likely reduced due to the loss of a thermal gradient, requiring increased dependence on evaporative heat dissipation. To determine if calliope hummingbirds (*Selasphorus calliope*, 2.5g) can maintain heat balance during hovering at higher temperature, we used infrared thermography, open-flow respirometry, and particle image velocimetry (PIV) to model their heat budgets at low T_a (~23 °C) and high T_a (~37 °C). Surprisingly, heat gain was higher at low T_a (0.30W) than at high T_a (0.17W) due in part to an 18% reduction in hovering metabolic rate. Total evaporative heat dissipation did not change across temperatures, but the contribution of respiratory evaporation decreased from 30 to 8% at higher temperature suggesting a restriction in respiratory evaporation. Because birds began panting while hovering at 36 °C it is likely that hovering at higher temperature was more challenging, and that the lower heat load predicted by our model might be due to under estimation of radiant heat gain. Heat stress during hovering at temperatures above 36 °C is consistent with our observations that hummingbirds in the field begin behaviorally regulating their surface temperature at ~38 °C.

P3-79 POWERS, MJ*; HILL, GE; WEAVER, RJ; BURTON, RS; Auburn University, Scripps Institution of Oceanography, University of California, San Diego; *mjp0044@tigermail.auburn.edu*

Hybrid Viability and Mate Choice in Highly Geographically Separated Populations of T. californicus copepods

Tigriopus californicus copepods are small benthic crustaceans with high levels of genetic structure among sites in coastal California and Oregon. Divergence in mitochondrial genotypes has been shown to be as high as 20% between California populations. Crosses among these genetically divergent populations produce hybrids with reduced fitness due to incompatibilities in co-functioning mitochondrial and nuclear OXPHOS proteins. Thus, post-zygotic fitness effects likely play a role in isolating copepod populations. Here we tested the hypothesis that pre-zygotic mechanism may also play a role in isolating copepod populations. Various copepod species, including *T. californicus*, have been documented to use chemical signals in mate choice. While avoidance of inbreeding has been demonstrated experimentally in genus *Tigriopus*, mate choice to avoid outbreeding beyond population boundaries has not been well studied. We first examined the hybrid viability in crosses between widely geographically separated *T. californicus* populations: Santa Cruz, CA (SCN) x Seal Rock, OR (SR) (1046 km), and Abalone Cove, CA (AB) x Seal Rock, OR (1524 km). We found that offspring from both crosses showed decreased survival rates, extended development times, and increased sterility when compared to control crosses (SR x SR). Given the fitness cost to hybrid pairing, we predicted that males would preferentially clasp same-population females versus other-population females. Preliminary data suggest that male copepods use chemical cues to avoid mating outside of local population boundaries.

S2-2 POWERS, JD*; WILLIAMS, CD; DANIEL, TL; Univ. Washington, Seattle, Allen Institute Cell Science; *danielt@uw.edu*

Tuning titin stiffness to optimize striated muscle contraction efficiency

In striated muscle, the giant protein titin spans the entire length of a half-sarcomere and extends from the backbone of the thick filament, reversibly attaches to the thin filaments, and anchors to the dense protein network of the z-disk capping the end of the half-sarcomere. However, little is known about the relationship between the basic mechanical properties of titin and muscle contractility. Here, we build upon our previous multi-filament, spatiotemporal computational model of the half-sarcomere by incorporating the nonlinear mechanics of titin filaments in the I-band. We vary parameters of the nonlinearity to understand the effects of titin stiffness on contraction dynamics and efficiency. We do so by simulating isometric contraction for a range of sarcomere lengths (SL; 1.5-3.0 µm). Intermediate values of titin stiffness accurately reproduce the passive force-SL relation for skeletal muscle. The maximum force-SL relation is not affected by titin for SL < 2.75 µm. However, for SL > 3.0 µm, maximum force significantly increases from 101 ± 2 pN to 112 ± 3 pN as titin stiffness increases. Additionally, by monitoring ATP consumption, we measure contraction efficiency as a function of titin stiffness. We find that at SL = 3.0 µm, efficiency significantly increases from 13.5 ± 0.4 pN/ATP to 15.5 ± 0.6 pN/ATP when increasing titin stiffness, with little or no effect below 3.0 µm. Taken together, our results point to a unique role of titin in determining muscle contractile efficiency.

P1-86 PRABHAT, A*; BATRA, T; KUMAR, V; University of Delhi; *drvkumar11@gmail.com*

Effect of Timed Food Availability on Daily Activity, Feeding and Grooming Behavior, and Testicular Growth in Zebra Finches

We investigated if the period of daily food availability affects circadian clock governed behavioral patterns and testis growth in zebra finches (*Taeniopygia guttata*). Adult male zebra finches were exposed to 12 h light: 12 h darkness, with food for 4 hours in the evening (hour 8-12 after light on), with controls on food *ad libitum* for different durations, 1, 3 or 4 weeks. We video graphed and monitored daily pattern in the perch hopping, feeding and preening behaviors, and measured changes in the food intake, body mass and testis size. Body mass did not differ within and between groups, but we found daily variations in birds under the restricted feeding paradigm, with a significant decrease and increase before and after the food availability periods, respectively, perhaps due to food storage in the crop. However, 24 h food intake was not significantly different between restricted *ad libitum* food availability groups. Also, birds spent similar time in eating in both food availability groups. Daily perch hopping and preening behaviors were altered in birds under restricted feeding regimen. Interestingly, birds showed a significant reduction in the testis size after 1 week of restricted feeding, but then the trend was reversed and testes began to regrow; at the end of week 3 and 4 of restricted feeding testes were not significantly different between two groups. These results show changes in the metabolism and reproductive strategies in animals when they are possibly faced with an unnatural food condition in their habitat. This work was funded by Science and Engineering Research Board (EMR/2015/002158), New Delhi.

P1-296 PRAKASH, VN*; BHARGAVA, A; PRAKASH, M; Stanford University; *vprakash@stanford.edu*

Local epithelial fractures and healing dynamics facilitate extreme shape change, morphogenesis and asexual reproduction by fission in Trichoplax adhaerens

Animals in their adulthood are often associated with a fixed shape and form, primarily determined by epithelial tissues, which hold organs and organ systems together. Here, we study morphogenesis in a simple, early diverging metazoan - the *Trichoplax adhaerens* (phylum *Placozoa*), known to exhibit a surprising amorphous 'amoeboid' shape change all throughout its adult form. The *Trichoplax* is one of the simplest known multicellular animals - with just six cell types and a flat, pancake-shaped three-layered body plan consisting of dorsal and ventral epithelial layers. Live microscopy reveals that adult animals are capable of real-time extreme shape changes and exhibit both a solid-like and liquid-like tissue behavior. In order to study this phenomenon, we developed a novel technique for large-scale cellular tracking over wide fields of view and long durations. We quantitatively link organism-scale shape changes to internal epithelial cell rearrangements by mapping their large-scale morphogenetic flow fields using micro-bead tags and cell tracking. We discovered that mechanical forces generated in these animals could result in physiological, localized, ventral epithelial fractures, which may either heal over time or enlarge in size, leading to large-scale cellular rearrangements and extreme shape changes such as long narrow threads. Under sufficient pulling forces, these threads may rupture, culminating the asexual reproduction process resulting in two or more daughter animals. We quantify these tissue fractures and other non-canonical tissue flow patterns, and demonstrate multi-scale tissue mixing over short and long time-scales.

85-3 PRAVIN, S*; HAN, E; JAEGER, HM; HSIEH, ST; Temple University, The University of Chicago; *tuh04350@temple.edu*
Foot Geometry and Kinematics of Impact Significantly Affect Force Generation in Granular Media
The effectiveness of animal locomotion on natural substrates like sand, soil, and snow depends on foot morphology, kinematics of foot motion, and substrate properties. The behavior of flowable ground is often complex, and the medium can both solidify and flow in a single step. We used the discrete element method to model the impact of the foot on dry granular substrate. The simulation was calibrated and the results were validated using intrusion experiments performed with a linear actuator (ETT model, Parker Hannifin Corp.) impacting a 28x28x7.5 cm container of poppy seeds at intrusion speeds up to 2 m/s. A circular disk, and a disk with three toes attached were used as intruder shapes, and the total force generated on the foot over the depth of intrusion was calculated. The presence of toes generated a larger amount of force on the foot and a larger volume of fluidized medium. Intrusion at greater speeds produced a larger peak force on impact and a greater rise in force subsequently with depth. Simulations were also performed at various angles of attack of the intruder where the foot was oriented at an angle to the substrate surface during intrusion. The greatest amount of impact force was observed when the surface of the foot made an angle less than 10 degrees with the free surface of the granular medium, beyond which the impact force rapidly decreased to less than 65 percent of the maximum value. These results demonstrate that the foot geometry and kinematics can significantly affect the force response experienced by the animal, and consequently determine locomotor performance.

P2-263 PROKKOLA, JM*; ALIORAVAINEN, N; LEMOPOULOS, A; HYVARINEN, P; VAINIKKA, A; Univ. of Eastern Finland, Natural Resources Institute Finland (Luke); *jenni_prokkola@hotmail.com*
Fishing for a Fast Pace-of-life: Does Vulnerability to Angling Have Heritable Effects on Physiology and Repeatable Behavior in Salmo trutta?
Human-induced selection caused by angling is a major selective force leading to phenotypic and genetic changes in fish populations, affecting their sustainability and responses to other environmental changes. Angling selects for individuals that show less explorative personalities, lower growth rate and earlier maturation, which could be reflected on a suite of other correlated traits. Our goal was to study the heritable effects of angling-induced selection on pace-of-life syndrome -related traits: growth, personality, stress responsiveness and minimum oxygen consumption (MO2min) in brown trout *Salmo trutta*. The parents of experimental fish were selected for high (HV) and low vulnerability (LV) to angling and bred with a fully factorial breeding design to produce progeny in common garden conditions. The HV and LV progenies were reared in hatchery conditions, tagged with passive integrated transponders (PIT-tags), and used in the experiments at the age of 1+ y.o. This study is among the first to assess whether offspring differ in correlated behavioral and physiological traits in relation to parent's vulnerability to angling. The results will give insight into fishing-induced evolution, as well as the process by which animal personality traits can evolve in natural populations.

94-2 PROKKOLA, JM*; HYVARINEN, P; ALIORAVAINEN, N; LEMOPOULOS, M; VORNANEN, M; VAINIKKA, A; Univ. of Eastern Finland, Natural Resources Institute Finland (Luke); *jenpro@uef.fi*
Food Availability and Genetic Background as Determinants of Partial Migration in Freshwater Brown Trout
Brown trout (*Salmo trutta*) show remarkable phenotypic variation in life-history traits, including migration tendency. Some populations are dominated by resident (non-migrating) and others by migrating individuals. Both environment and genetic background influence the life-history strategies, but the strength of the genetic component is poorly understood. Here, we studied how rearing conditions and genetic background affect the smolting process and smolt migration activity. We reared one supposedly migratory, one supposedly resident population of brown trout and their F1-hybrids in common-garden conditions. The fish were tagged with PIT-tags and the experiments were performed when the fish were 2-3 y.o. Fish were divided equally in semi-natural streams with ambient temperature lake water. Half of the tested fish were introduced to the stream from hatchery conditions during the winter, while the other half of the fish fed on natural food sources in the streams starting from the previous autumn. Fish movement and its direction were monitored using four PIT antennas in each stream. On the second year of smolting, 53 fish were euthanized during peak migration and gill samples collected for measuring Na,K-ATPase activity and the number of Na,K-ATPase pumps -indicators of smolting process in anadromous salmonids. Both were higher in fish from the migratory than the resident population, and intermediate in hybrids, suggesting smolting physiology has a strong genetic component even after a long isolation in freshwater. We found similar results on downstream swimming activity. Overall, the study gives a more insight to how life-history decisions are regulated by the environment and the genetic background.

P2-103 PROVENCHER , CA*; PLACHETZKI , DC; PANKEY , S; University of New Hampshire ; *cao256@wildcats.unh.edu*
Phylogenteic Focusing Reveals the Evolution of Eumetazoan Opsins
Phylogenetic analyses of gene trees commonly begin by searching large molecular datasets from the taxa of interest using some known query sequence. Resulting sequences that exceed some threshold are then concatenated, aligned and analyzed phylogenetically. This approach has revealed much about the evolutionary history of gene families, but several problems are apparent. Here we apply a new approach that we call phylogenetic focusing that circumvents issues related to global search strategies. Our approach first circumscribes the largest possible orthogroup containing the gene family of interest and then proceeds to focus the dataset based on iterative rounds of phylogenetic analysis. We demonstrate this approach by using the phylogeny of eumetazoan rhodopsin class GPCRs to focus in on a clade containing melatonin receptors, opsins, and other genes. Our results clarify the evolutionary history of eumetazoan rhodopsin class GPCRs and the subclade containing opsins and provide new hypotheses on the functional significance of these genes in cnidarians.

30-2 PROVINI, P*; VAN WASSENBERGH, S; Museum National d'Histoire Naturelle, Paris; *pauline.provini@mnhn.fr*

Suction outflow dynamics in fishes: effects of the shape of the pharynx and pectoral region of the body

To capture prey by suction, fishes generate a flow of water that enters the mouth, and exits at the back of the head. It was previously hypothesized that a streamlined shape of the posterior pharynx and the pectoral region of the body are important to enable an unobstructed outflow with minimal hydrodynamic resistance. However, due to the lack of optical access into the pharyngeal cavity, and the limitation of biomechanical models, this hypothesis remained untested. With the help of computational models, allowing a dynamic simulation of both inflow and outflow of water, as well as graphical reconstructions based on CT-scans of a percomorph species of fish (*Lepomis gibbosus"*), we were able to test the influence of the shape of the buccal cavity on water flow. We found that modifying a wedge-shaped protrusion of the pharynx near the region of the oesophagus entrance into a straight surface perpendicular to the incoming flow has a negligible effect on the dynamics of suction feeding. This suggests that suction feeding does not strongly constrain the shape of this region, which provide new insights on the functional morphology of suction outflow.

P3-166 PROVINI, P*; HöFLING, E; Museum National d'Histoire Naturelle, Paris, Universidade de São Paulo, São Paulo; *pauline.provini@mnhn.fr*

Evolution of Hopping and Arboreality in Neotropical Birds

Birds can use different types of gaits to move on the ground: they either walk, hop, or run. Although preference for running can easily be linked to velocity, it remains unclear what drives a bird to walk rather than to hop at moderate speeds. As it appears that many hopping birds are arboreal, we wanted to test an arboreal origin of hopping. To explore this question, we carried out ancestral character state reconstructions of both hopping ability and lifestyle on a wide diversity of Neotropical birds (N=96 species). Then, we quantified the morphological differences of the pelvis and the three long bones of the hindlimbs in 26 species of birds with different habitats and gait preferences. We used geometric morphometrics on 3D landmarks, digitized on micro-CT scans of the specimens. We found that hopping ability and arboreality were both derived traits in avian evolution and that the shape of the pelvis, femur, tibiotarsus, and tarsometatarsus carried a strong phylogenetical signal, reinforcing the importance of performing our analysis in a phylogenetical context. Our geometric morphometrics analysis revealed that the locomotion habits significantly influence the shape of the pelvis, femur and tibiotarsus, but not the shape of the tarsometatarsus: hopping birds tend to have a less elongated and broader pelvis than walking bird, with a straighter femur. These features may provide efficient propulsion and dampening of the forces involved in hopping and could confer a selective advantage to move in the trees. This work provides elements on a potential arboreal origin of hopping and on the evolution of avian locomotion, which could help us better understanding the evolution of theropod dinosaurs.

53-2 PRUETT, JE*; WARNER, DA; Auburn University; *jep0057@auburn.edu*

The Influence of Maternal Nesting Behavior and Nest Microhabitat on Embryo Development and Offspring Fitness Across Early-life Stages.

Phenotypic plasticity, or the ability of a single genotype to express multiple phenotypes, is critically important in fluctuating or changing environments. Developmental and embryonic life stages are particularly sensitive to their environment, especially in oviparous taxa that lack of parental care. Thus, the location that mothers choose for nesting has important consequences on fitness. When choosing an oviposition site mothers must assess both (1) the conditions (both biotic and abiotic) that offspring will experience during development, and (2) the location of the nest in relation to resources offspring may need after hatching. To quantify the influences of nest site microhabitat, location, and maternal effects on offspring, we studied the Western Painted Turtle (*Chrysemys picta*), which has a unique life history trait where hatchlings remain in the nest over winter. We observed nesting behavior at Round Lake State Park in Northern Idaho, and used a cross-fostering experiment to quantify the contributions of maternal identity and nest microclimate to variation in offspring survival and phenotype. Specifically, I manipulated two variables that are important to development and post-hatching dispersal (shade cover and distance to water) to determine their effects on development and offspring fitness. Because shade cover has significant effects on summer and winter nest temperatures, we predict that these factors contribute to variation in offspring phenotypes and survival at the embryo, over-winter, and dispersal stages.

P1-47 PUNITH, LK*; MCKNIGHT, M; NARSIPUR, S; DICK, TJ; SAWICKI, GS; Georgia Tech, NC State, Univ of Queensland; *lpunith@gatech.edu*

Muscle-Tendon Units Can Automatically Reject Perturbations Without Feedback During Everyday Cyclic Tasks

Terrestrial animals navigate complex and unpredictable terrain with agility and safety during everyday cyclic tasks. Birds achieve this by a proximo-distal gradient in their joint motor control strategy (Daley et al., 2007). However, the mechanical behavior and neuromuscular control at the individual muscle-tendon unit (MTU) level during perturbations remains unclear. To address this, we used a Hill-type MTU with an antagonist catch in a hopping paradigm (Roberston et al 2014). The MTU was cyclically stimulated by a combination of feedforward and positive force feedback control signals. A substrate height perturbation was applied and simulated until steady state behavior. This was done for varying levels of feedback and feedforward signals. Our results suggest that feedforward dominated strategies have adequate settling times, the lowest muscle strains, the highest amount of energy dissipation, and the lowest energetic demands. This is achieved by a shorten-stretch cycle where the muscle is pre-activated and shortens against the tendon due to delay in ground contact while falling in a hole. This allows the tendon to rapidly stretch and initially absorb the energy of the fall whilst enabling the muscle to re-absorb it over a longer period with the added benefit of force-enhancement. This is achieved without requiring complex neural control and is a fundamental property of the perturbation response of feedforward dominated MTUs during cyclic tasks which has also been experimentally shown in animals and humans. In conclusion, we propose that sensory feedback may not be the dominant strategy for maintaining stability in the face of uneven terrain. However, it may play an important role in triggering antagonist co-activation to generate a muscle-based latch mechanism which enables muscle pre-shortening to maintain stability and prevent muscle damage.

102-5 PUTMAN, BJ*; BLUMSTEIN, DT; PAULY, GB; University of California Los Angeles, Natural History Museum of Los Angeles County; *putman.bree@gmail.com*

Anthropophobia and Lizard Responses to Urbanization in Southern California

Urbanization is occurring rapidly worldwide and is one of the greatest threats to biodiversity. How animals assess and respond to novel threats will likely predict who survives such rapid environmental change. In particular, human activity affects animal behavior and physiology (via the HPA axis), and individuals may need to modify responses to humans in order to co-exist with them in urbanized environments. We have categorized various lizard species in Southern California as urban intolerant, urban tolerant, or urban exploitive, and are quantifying behavioral and physiological fear responses to determine if anthropophobia (fear of humans) associates with intra- or interspecific differences in urban tolerance. Thus far, we have found that three species of nonnative lizard (urban exploiters) have higher escape responses from approaching humans and remain closer to refuge than native Western fence lizards (*Sceloporus occidentalis*), suggesting that an overall wariness of danger could promote establishment success in foreign habitats. Urban lizards also perceive humans differently based on clothing color, indicating that they are sensitive to nuanced aspects of human behavior. Across sites that vary in urbanization and human activity level, we find that the availability of good quality natural habitat promotes habituation to humans (reduction in fear responses), but lack of natural habitat could lead to sensitization and negative fitness effects. In addition to various behavioral measures, we are quantifying endocrine responses that could help maintain homeostasis in challenging environments.

34-8 PUTNEY, J*; BARKER, R; SPONBERG, S; Georgia Institute of Technology, Emory University; *jputney3@gatech.edu*

Redundancy and Consistency of Muscle Encoding Strategies in Hawk Moth Flight

Animals utilize neural control distributed across many muscles when tracking or navigating through natural environments. A growing body of evidence shows that temporal encoding is used to precisely time muscle activity in a variety of behaviors at many different speeds and in a diversity of animals. While encoding has been examined in single motor units, movement is actuated by muscles with different functions, and little is known about how information is encoded across multiple muscles. Previously, we recorded a spike-resolved motor program of unprecedented completeness in the hawk moth (*Manduca sexta*) as it tracked a robotic flower with a simple 1 Hz sinusoidal trajectory in tethered flight. We showed that both temporal and rate encoding mechanisms had significant mutual information with the flower's position. We have now obtained the forces and torques produced during this behavior using a six-axis force-torque transducer and developed analysis that allows us to consider the net redundant or synergistic information across pairwise combinations of muscles. We show that both temporal and rate encoding mechanisms inform the turning (yaw) torque of the moth, and that the magnitude of temporally encoded information is higher than the magnitude of rate encoded information for all muscles. We demonstrate that pairwise combinations of muscles encode net redundant rather than synergistic information, and that most of this net redundant information is found in the temporal code. Finally, we find no evidence for differences in encoding strategy between putative flight power and steering muscles. These results indicate that motor encoding strategies may be consistent across muscles regardless of their different functional roles.

P1-2 PYLES, RA; East Tennessee State University; *pylesr@etsu.edu*

Adding Quantitative Skills to Comparative Vertebrate Anatomy

This Comparative Vertebrate Anatomy course emphasizes phylogenetic and functional/biomechanical approaches to understanding anatomical characteristics. Course content is organized regionally, with major units on cranial morphology and feeding; appendicular/axial morphology and locomotion; and then coverage of organ systems. To enhance this approach and incorporate recommendations of "Vision & Change" and departmental learning outcomes, morphometric projects were added to expose students to analyses of skeletal shape associated with different modes of feeding and locomotion. Projects are assigned after the appropriate lectures and after students complete surveys of the skeletons and muscles. Student teams (2-3 individuals) collaborate to obtain skeletal measurements on two or three species (10 individuals each); organize data; apply statistical and graphical analyses; and present their findings in oral presentations. For the first project on feeding morphologies, the instructor guides discussion of possible outcomes and selection of measurements on two species. Each team adds two measurements of their own selection and submits a spreadsheet of the organized data. The second project focuses on locomotion and is entirely student-driven, with each team selecting species for comparison, developing hypotheses and selecting appropriate measurements. A few weeks after the second projects, students are asked to evaluate the projects, providing opinions about value of the projects and whether to retain them in the course. Since 2015, student response has been very positive, with 100% expressing the opinion that projects should be retained. "They make learning the material interesting. We have to use research and critical thinking to come up with explanations for the results." Most frequently expressed student responses will be presented.

P1-41.1 QUATTRINI, AM; FAIRCLOTH, BC; RODRIGUEZ, E; MCFADDEN, CS*; Harvey Mudd College, Louisiana State University, American Museum of Natural History; *mcfadden@g.hmc.edu*

Phylogenomics of class Anthozoa (Cnidaria) Using Universal Target-Enrichment Baits

The anthozoan cnidarians (e.g., corals, sea anemones) are an ecologically important and diverse group of marine metazoans that occur from shallow to deep waters worldwide, and include some of the ocean's most important ecosystem engineers. Our understanding of the evolutionary relationships among the ~7500 species within this class is, however, deeply flawed. Molecular phylogenetic studies have revealed widespread homoplasy in morphological characters and widespread polyphyly at the ordinal, family, and genus levels. Resolution of both deep and shallow nodes in the anthozoan phylogeny has been hindered by a lack of phylogenetically informative markers that can be sequenced reliably across taxa whose divergence may pre-date the Cambrian. While recent phylogenomic analyses have supported the reciprocal monophyly of sub-classes Octocorallia and Hexacorallia, resolution of the ordinal relationships within each clade requires more comprehensive taxon-sampling than can be achieved with transcriptomic approaches. Using all available anthozoan genomes and transcriptomes, we designed a set of 16,308 target-capture baits for enriching both ultraconserved elements (720 loci) and exons (1071 loci). Target enrichment was tested on 33 taxa representing all orders of Anthozoa. Illumina sequencing of enriched genomes recovered 1774 of 1791 targeted loci, with a mean of 638 ± 222 loci recovered per species. Maximum likelihood analyses yielded highly resolved trees with topologies matching established anthozoan relationships. We have now sequenced >200 taxa representing a majority of the known families of Anthozoa, and report here on the ability of these markers to resolve both deep and shallow relationships within the class.

P3-268 QUIGLEY, KM; WILLIS, BL; KENKEL, CD*; Aust. Inst. of Mar. Sci., James Cook Univ., AUS, Univ. of So. California; *ckenkel@usc.edu*

Symbiont shuffling as a parental effect in a vertically transmitting coral

Adult organisms may "prime" their offspring for environmental change through a number of genetic and non-genetic mechanisms, termed parental effects. Some coral species can alter their thermal tolerance by shuffling proportions of their symbiont communities, but it is unclear if this plasticity can prime larval offspring in corals exhibiting maternal symbiont transmission. We evaluated symbiont community composition in tagged *Montipora digitata* from Orpheus Island, AUS, over two successive annual spawning seasons, the second of which overlapped with the 2016 mass coral bleaching event on the Great Barrier Reef. We applied amplicon sequencing of the ITS2 locus in four families (adult colonies and ten eggs per family) to characterize the potential for symbiont shuffling and to determine whether or not shuffled abundances are preserved in gametes. Symbiont cell densities and photochemical efficiencies of the symboints' photosystem II differed significantly among adults in 2016, suggesting differential responses to increased temperatures. The dominant symbiont haplotype, a representative of clade C15, was not significantly different among families or over time. However, low-abundance ("background") ITS2 types differed more among years (2015 vs. 2016) than between life stages (parent vs. offspring), suggesting that background shuffling can occur and that these symbiont community changes are heritable. Although more work is needed to establish the role of background symbionts in holobiont thermal tolerance, this is the first evidence of shuffling extending to early life-history stages and provides evidence that plastic changes in microbial communities may serve as a mechanism of coral acclimation to changing environmental conditions.

36-5 QUINN, B.L.*; CARTER, A.M.; HSIEH, S.T.; Temple University, Univ. of Pennsylvania; *brooke.quinn@temple.edu*

Bending Rules for Terrestrial Locomotion

Natural animal propulsors show high levels of energetic efficiency in their movements which man-made propulsors have not yet been able to adequately replicate. The analysis of bending patterns of terrestrial animals could provide insight into the construction of man-made propulsors. This study was modeled after a previous paper by Lucas et al. (2014), which showed that during swimming and flight, regardless of medium and phylogeny, all examined animals moved their propulsors in a similar manner using predictable, characteristic motions. Whether similar sets of rules apply during terrestrial locomotion remains unknown. Using 88 videos representing 50 vertebrate species obtained from open source platforms and contributed research videos, we quantified bending during propulsion by calculating a maximum flexion angle (FA) and flexion ratio (FR) in terrestrial vertebrates. Maximum flexion angle is defined as the minimum acute angle made by the vertex around which bending centered. Flexion ratio was calculated as the ratio of the distal segment relative to the total propulsor length, as centered about the vertex. Phylogenetic generalized least squares analyses illustrated significant but low K values for both flexion metrics (FA: $K=0.161$, $p=0.001$, FR: $K=0.289$, $p=0.001$), implying a weak evolutionary basis to the observed patterns, and that they instead are driven by other factors, such as foot posture, environment, and gait. Phylogenetic ANOVAs showed that locomotor foot posture (i.e., plantigrade, digitigrade, and unguligrade) had no statistical effect on maximum flexion angle ($F=2.14$, $p=0.13$) or flexion ratio ($F=3.19$, $p=0.05$). These results suggest that as for flight and swimming, terrestrial locomotion is also constrained by a set of constrained bending rules.

S5-4 QUINN, D.B.; KRESS, D; STEIN, A; WEGRZYNSKI, M; HAMZAH, L; LENTINK, D*; Stanford University; *dlentink@stanford.edu*

How Birds Negate Gusts and Maintain Heading by Crabbing into the Wind

Everyday observations show birds flying stably in strong lateral gusts in which aerial robots cannot operate reliably. However, the mechanisms that birds use to negate lateral gusts are unknown. Therefore, we studied the motions of lovebirds as they flew through strong gusts in a long mesh corridor. The corridor was painted to simulate a forest (vertical stripes), a lake (horizontal stripe), and a cave (dark with a small light at the end). Fan arrays outside the corridor imposed three wind conditions: still air, a uniform gust, and wind shear. We found that lovebirds consistently yaw their body into the wind direction, crabbing like a fixed-wing aircraft, while keeping their head oriented towards the landing perch, unlike aircraft. Remarkably, these results were the same for all three visual conditions, showing how lovebirds can even negate gusts in the dark with only a faint point light source as a target. Furthermore, because the naive birds had never experienced gusts before, the gust mitigation behavior is innate. Motivated by these observations, we developed a physical model to mechanistically explain wind negation in birds. The findings offer inspiration for designing aerial robots that are robust to gusts.

41-4 RABOIN, M*; ELIAS, D.O.; Univ. Of California, Berkeley; *maggie.raboin@berkeley.edu*

Deconstructing the mason spider mound: mound building behavior, function, and ecology in spiders

Animal builders are littered throughout the known animal kingdom and the structures they construct are highly diverse in form and function. Animals build structures to modify their immediate environment and thus control environmental and ecological factors to increase their fitness. Spiders are well known for their building behavior because many of them construct structures such as elaborate webs for prey capture and excavated burrows for protection. Mason spiders are unique among spiders because they do not construct typical webs or burrows; they build mounds. They construct mounds by stacking pebbles and dried leaves on top of their egg cases and sealing each piece of debris in place with silk. Despite the conspicuous nature of the mason spider's mound building behavior, the function of these mounds is unknown. We conducted a field experiment to determine if mounds protect mason spider eggs from (1) parasitism by wasps, (2) fluctuating temperatures, or (3) desiccation. During the summer of 2017, we manipulated mounds at four different time intervals following their construction. After some time, we collected and dissected egg cases to determine the rates of parasitism, desiccation, mortality, and stage of development for each egg case. Our results suggest that mounds function in a variety of contexts. We suggest that mounds allow spiders to survive the extreme conditions of their natural habitats.

S11-6 RABOSKY, Daniel L; University of Michigan;
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Speciation, extinction, and the assembly of global vertebrate diversity
Far more species of organisms are found in the tropics than in the Earth's temperate and polar regions, but the evolutionary and ecological causes of this pattern remain controversial. I explore the role that differential rates of speciation and extinction have played in generating large-scale gradients in the diversity of vertebrate animals in the oceans and on land. In the marine realm, tropical fish communities are much more diverse than coldwater communities found at higher latitudes, and a major class of explanations for this latitudinal diversity gradient proposes that warm reef environments serve as evolutionary "hotspots" for species formation. I assess relationship between latitude, species richness, and diversification rates across marine fishes, and I compare these patterns to those for several major groups of terrestrial vertebrates. I conclude by discussing ways in which the diversification-diversity relationship may vary across the Tree of Life.

P3-149 RADER, JA*; HEDRICK, TL; UNC Chapel Hill;
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3D Shape Variation in Bird Wings: How Useful are Spread Wing Collections?
The wings of flapping fliers are multi-purpose structures responsible for the generation of lift to support the body weight of the flier, thrust for forward flight, and directional forces for maneuvering. The relative importance of each of these functions and of flight as a whole differs among species with different flight styles and ecological pressures. Consequently, wing morphology is expected to display variation corresponding with those functions. Numerous studies have examined planform (i.e. two dimensional) avian wing shape in a variety of contexts, ranging from biomechanical studies of flight efficiency and migration to broad phylogenetically-controlled investigations of character evolution. In addition to planform variation, three-dimensional (3D) attributes of wing morphology such as camber, span-wise twist, and taper may also vary significantly among species and contribute to aerodynamic function, but have received less attention. This is likely, in part, because the advent of technology to quickly acquire 3D data is relatively recent, and applying those techniques to living animals remains challenging. To address this difficulty, we evaluated the utility of preserved spread wings in museum collections to studies of 3D wing morphology. One hundred and fifty wings from seven species of predatory birds (*Accipiter cooperii*, *A. striatus*, *Buteo jamaicensis*, *B. lineatus*, *Falco peregrinus*, *F. columbarius* and *F. sparverius*) spanning an order of magnitude of body mass and with three-fold variation in wingspan were scanned using a NextEngine 3D Scanner Ultra HD laser scanner (NextEngine, Inc.). The 3D data were analyzed using a custom program in MATLAB to assess interspecific and intraspecific variation and the reliability of metrics derived from such scans. We discuss the utility of this approach for future studies of morphology and biomechanics.

P2-43 RAHMAN, MD/S*; HERNáNDEZ, E; VáZQUEZ, O; RANGEL, V; CANTú, E; University of Texas Rio Grande Valley, Brownsville; *md.rahman@utrgv.edu*
Impacts on global warming on gonadal functions in Atlantic sea urchin
Global warming is a phenomenon that is increasingly difficult to deny and has been linked to the increasing temperature of sea water which is a form of environmental stress for aquatic organisms. To understand the effects of feverish temperature on gonadal functions in economically and environmentally important marine invertebrates, Atlantic sea urchin were collected from South Padre Island in the Gulf of Mexico and placed in six aquariums (capacity: 20-gallon) with high temperatures (28 and 32^{o}C) and control variable (24^{o}C) under controlled laboratory conditions. After one week of exposure to different temperatures, gonadal tissue samples were collected to analyze the effects of warmer temperature on gonadal apoptosis and reproductive functions in sea urchin. Gonadal tissues were sectioned and stained with hematoxylin-eosin, and the proportions of mature egg (ova) and sperm contents were determined. Sea urchin exposed to high temperatures had the lowest gonadosomatic index compared to controls. Ovaries and testes from sea urchin exposed to high temperature showed a decrease in the proportion of ova and sperm contents, respectively. Colorimetric in situ TUNEL assay and caspase activity were also conducted to evaluate cellular apoptosis in gonadal tissues. Ovaries from sea urchin exposed to high temperature showed an increased proportion of TUNEL-positive cells compared to controls. Massive apoptotic cells detected by TUNEL signals were also observed in testicular tissues after exposure to high temperature. Caspase activity was significantly increased in ovary and testis protein of sea urchin exposed to high temperature compared to controls. Collectively, our results suggest that elevated water temperature induces gonadal apoptosis which might be involved in the impairment of reproductive functions in Atlantic sea urchin.

P1-301 RAHMAN, M*; CONRAD, BD; FOX, M; KERSH, ME; POLK, JD; University of Illinois Urbana-Champaign;
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Exercise and postural effects on subchondral and trabecular bone
Subchondral and trabecular bone comprise the ends of long bones and underlie articular surfaces. These tissues provide for a combination of transmission of joint force to stronger cortical bone and some compliant absorption of loads. Both tissues are known to respond to different patterns of loading by increasing apparent density or aligning to trabecular orientation to the direction of applied loads, respectively. Our research program tests how experimentally induced differences in exercise and joint postures affect local stiffness and strength of subchondral and trabecular tissues and alter load transmission through the whole epiphysis. Fifteen lambs ($\bar{x}$=60d) were assigned to one of three groups: (i) incline treadmill exercise (15% grade), (ii) flat treadmill exercise, and (iii) non-exercise controls. The first step toward this goal involves characterizing the magnitude of postural and loading differences within and between treatment groups. Groups (i) and (ii) were exercised twice daily at 2.5m/s for 20 min/bout. Kinematic data were obtained using a Qualisys motion capture system and ground reaction forces were obtained for incline and flat locomotion for all individuals. All sheep were housed together in an indoor enclosure at the University of Illinois Sheep and Beef Cattle facility. Ground reaction forces did not differ significantly between incline and flat walking, and preliminary analysis of knee joint angles shows that the incline group used more flexed knee postures at midstance than exercise or control groups. These results will be used to explain local differences in structural characteristics of subchondral and trabecular structures and to test hypotheses about the functional characteristics of epiphyseal structure. Funded by NSF BCS-1638756; University of Illinois Research Board.

42-3 RAIZA, C*; ELIAS, DO; University of California, Berkeley;
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Hidden Instruments of the Spider Serenade: comparative morphology of sound producing structures in jumping spiders

Animal signals can be highly diverse even in the same genus . Male jumping spiders in the hyper diverse genus *Habronattus* court females by performing a series of complex displays that include visual and vibratory signals. These multi-modal displays vary widely across species, and it is unclear what structures males use to produce their vibratory songs. We examined variation in sound producing morphology across the group using a combination of of video and imaging techniques. We documented male songs of different species using high speed video recordings and laser vibrometry and then imaged their song producing structures using Scanning Electron Microscopy. Comparisons of the imaged structures reveal distinct morphologies across different species groups but similar morphologies between sister taxa. Our work suggests that the evolution of different song producing mechanisms may have driven diversification in the group.

31-2 RAJA, SV; RAMESH, L; VATS, A; SANE, SP*; National Centre for Biological Sciences, Tata Institute of Fundamental Research; *sane@ncbs.res.in*

Collective self-organization of traffic in mound-building termites

Social insects, such as honeybees, ants and termites are excellent model systems to understand how organisms collectively self-organize to cooperatively carry out tasks relevant for their survival. Mound building termites are especially interesting in this regard because they build extraordinary structures to house their colony. Within these large structures is a maze of narrow passageways that they traverse in an efficient manner, a task that is especially challenging because these termites, barring their alate forms, lack image-forming eyes and live entirely underground where light does not penetrate. What sensory cues govern the traffic of termites under such conditions? To study this question, we developed a behavioral assay in which the termites (*Odontotermes obesus*) were placed in a circular arena with a confining sleeve and their behavior filmed using an overhead camera. We observed that such termites milled around the arena in a regular fashion, and this behavior was density-dependent. We proposed the hypothesis that milling results from physical processes such as those seen in bristlebots - vibrating robotic devices that self-organize through a passive mechanical process. An alternative hypothesis requires the presence of sensory cues to drive such behavior. To test these hypotheses, we removed the bounding sleeve of the arena, and observed that, once established, the milling persisted. Replacing these termites with a naïve set established milling in absence of the confining sleeve. However, replacing part of the arena floor with a fresh floor disrupted the behavior. These observations show that milling behavior is initially established by mechanical cues, but later sustained by the chemical trails laid down by the termites.

1-4 RAMENOFSKY, M*; OLSON, S; PAN, C; BOSWELL, T; University of California, Davis, Queen's University, Canada, Newcastle University, U.K., Newcastle University, U.K.;
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Role of photoperiod and nutritional state on the regulatory feeding mechanisms in Gambel's White-crowned Sparrow

For many migrants the annual increase in day length initiates development of behavioral and physiological traits requisite for long distance flight. One such trait is hyperphagia leading to increased body mass and fuel (fat) deposition. A number of neuropeptides are known to regulate energy balance in mammals and domestic fowl but how photoinduction influences gene expression that enhances food intake in migratory birds is poorly understood. To gain insight we measured body mass and daily food intake in 3 groups of Gambel's White-crowned Sparrows: short-day controls held on a winter photoperiod, 9L:15D, long-day experimentals that included one and two day exposure to a long photoperiod 20L:4D to record the effect of photoinduction on premigratory hyperphagia. Photoinduction was associated with increased food intake ($P<0.05$) and body mass ($P<0.05$). Additionally, mean agouti-related protein (AGRP) mRNA was increased ($P=0.02$) on the first long day that was accompanied by a respective decrease ($p=0.003$) and increase ($p=0.015$) in the alpha 1 and alpha 2 catalytic subunits of the cellular energy sensor AMP-activated protein kinase (AMPK). Exposure to long days also significantly increased the mean ratio of iodothyronine deiodinase 2/deiodinase 3 mRNA by 17-fold on the first long day ($p=0.001$) and by 97-fold on the second long day ($p=0.001$) compared to the short day level. These results suggest that photostimulation coordinates changes in expression within the basal hypothalamus of deiodinase and AMPK enzymes to stimulate AGRP gene expression. The consequent increased signaling activity of AGRP neurons may promote premigratory changes in feeding and metabolism.

40-2 RAMIREZ, MD*; CANNON, JT; OAKLEY, TH; Univ. of Massachusetts, Amherst, Univ. of California, Santa Barbara;
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Octopus skin 'sight' may have evolved through the co-option of a deeply homologous dispersed light sense in mollusc mantle

At macroevolutionary timescales, do novel behaviors evolve through reuse and tinkering of pre-existing underlying components? We asked whether deep homology of a dispersed light sense in mollusc mantle may have contributed to the evolution of Light-Activated Chromatophore Expansion (LACE), a novel behavior of the colored chromatophore organs in octopus skin. Opsins are the primary way animals sense light, and we have previously hypothesized that LACE uses the same r-opsin phototransduction cascade to sense light as octopus eyes. We surveyed the literature and 45 publicly available mantle transcriptomes from major molluscan lineages for the expression of opsins and related cascade genes. R-opsin cascade genes are expressed in the mantles of 18 species from 5 molluscan classes. We combined these results with mantle expression data from the literature, bringing our total count of r-opsin expressing mantles to 21. The broad distribution of r-opsin expression in mantle across molluscs suggests that ancestral cephalopod skin likely sensed light before chromatophore organs evolved. The molecular basis for light sensing, r-opsin phototransduction, is already known as a deep homology, since r-opsins arose by the last common bilaterian ancestor. Our results are consistent with the hypothesis that the dispersed light sense in the mantle is also deeply homologous and pre-dates the origins of cephalopod chromatophores and their LACE behavior in response to light, suggesting that deep homology and co-option may be important for macroevolution of behavior.

35-5 RAMIREZ, RW*; COE, BH; WOLF, BO; University of New Mexico; *ricram@unm.edu*

Comparative Thermoregulation in Mojave Desert Rodents

As predictions of higher temperatures loom on the horizon, many climate models also predict increased magnitude and frequency of extreme heat events. Species' distribution, in part, depend on physiological tolerances and performance. Nocturnal rodents will increasingly be subject to warmer conditions, which may directly impact activity periods and their abilities to balance water and energy budgets. We examined the relative thermoregulatory capacities of members of a rodent community to assess the potential effects of a warmer environment on animal performance. Specifically, we measured the thermoregulatory function of Cricetid (*N. albigula, N. lepida, P. eremicus, P, crintus*) and Heteromyid rodents (*D. merriami, C. formosus, and C. spinatus*) at three sites in the Mojave Desert with differing average air temperatures. We used flow-through respirometry to measure resting metabolic rate (CO2 production) and evaporative water loss while continuously measuring body temperature over a wide range of air temperatures. We compared performance as a function of body size, taxonomy and site to examine the potential effects of warming and extreme events on relative animal function. Results suggest only small differences in RMR, EWL, and body temperature within species among sites.

121-3 RANGEL, RE*; JOHNSON, DW; California State University Long Beach; *racine.rangel@gmail.com*

Effects of Temperature and Mass on the Metabolic Rate of a Sedentary Reef Fish, The Bluebanded Goby (Lythrypnus dalli)

As climate continues to change, many marine species will experience both an increase in average temperature and more extreme diel and seasonal fluctuations. Understanding how these variations in ocean temperature affect processes such as metabolism and energy consumption is important for many species, and particularly so for sedentary species that cannot make large-scale movements in response to changes in environmental conditions. We examined how metabolic rates and energetic demands responded to temperature in a temperate reef fish, the bluebanded goby *(Lythrypnus dalli)*. Using respirometry, we estimated resting oxygen consumption (VO_2) and calculated metabolic rates (MR) at three different temperatures (13°C, 16°C, and 20°C) for 42 *L. dalli* individuals of varying sizes. As predicted, VO_2 and MR increased significantly with temperature and mass, but the rate of temperature-dependent increase in metabolism indicated a very high degree of thermal sensitivity for L. dalli (Q_{10} value for VO_2 was 5.56 across the range of experimental temperatures). The mass-scaling coefficient *(b)* was estimated to be 1.01 and aligned closely with other benthic species. Thermal fluctuations likely play a significant role in the ecology of these gobies and continued increases in seawater temperature will either necessitate an increase in foraging and consumption or drive costly trade-offs between metabolism and processes such as growth and reproduction.

10-7 RAUSCHER, MJ*; FOX, JL; Case Western Reserve University; *mjr67@case.edu*

Fly optomotor response dynamics are influenced by exogenously induced haltere movements

Like other flies, *Drosophila* stabilize their gaze in response to both visual and inertial self-motion cues. The former are sensed by the fly's compound eyes and the latter by the fly's halteres, reduced hind wings that act as body rotation sensors. Gaze-stabilization reflexes mediated by each sense modality can operate independently of those mediated by the other sense, but previous work has shown that *Drosophila* flying on a tether (and thus generating no inertial self-motion cues) nonetheless exhibit deficits in visually-guided head movements when the halteres are ablated [Mureli et al. 2017]. Together with neurophysiological data from *Calliphora* [Huston and Krapp 2009], these works suggest that halteres modulate descending visual inputs to neck motoneurons. However, no study has characterized the influence of specific parameters of haltere kinematics on optomotor gaze in a flying, behaving animal. Using a tethered flight arena equipped with electromagnets, we induced motion in one of the halteres at one of several frequencies (or rendered it immobile) while showing the fly a periodic visual motion stimulus designed to a elicit yaw optomotor gaze responses. Flies with an immobilized haltere showed similar dynamics in their optomotor gaze-following versus intact controls, with the exception that their head movements were centered at a fixed offset from the body axis. Upon reintroduction of periodic haltere motion using the electromagnets, this offset was diminished. At the highest tested frequency, the offset was diminished significantly further, approaching that seen in matched intact controls. These findings suggest that haltere inputs spanning a wide frequency range are sufficient for supporting normal optomotor gaze responses in *Drosophila.*

P2-129 RAWSON, P*; RICE, L; LINDSAY, S; University of Maine, Orono; *prawson@maine.edu*

Molecular and Morphological Analysis of Bivalve Shell Borers in the Genus Polydora from the Eastern U.S.

Marine polychaetes in several genera, including Polydora, Pseudopolydora and Boccardia, are known to excavate burrows in the shells of bivalves and other mollusks. Species of shell-burrowing worms in the genus Polydora described from the Atlantic and Gulf coasts of the U.S. include *P. websteri, P. concharum*, , *P. commensalis* and *P. neocaeca.* While fascinating to natural historians because of their unique burrowing habits, worms that inhabit the shells of commercially important shellfish are considered pest species because their burrowing activity can negatively impact shellfish appearance, and severe infestations can lead to shellfish mortality. Using a combination of morphological analyses and sequencing of mitochondrial COX1 and nuclear 18S rRNA genes, we examined the taxonomic affinity of polydorids sampled from the shells of scallops and oysters cultured at five shellfish farms located from Alabama to Maine. We found that *P. websteri*, the most common polydorid in oysters from these five farms, was nearly identical at both genetic markers to *P. websteri* from Asia and Australia. We obtained samples of *P. neocaeca* from both scallops and oysters at one site in Massachusetts. Morphological and molecular analyses suggest that *P. neoceaca* from this site is identical to *P. haswelli*, a species previously described from Japan. These same analyses provide evidence that worms sampled from one farm in Maine are identical to *P. onagawaensis*, another species first described from northeastern Japan. Taken together, our results support the conclusions of Sato-Okoshi and others that shell-boring polychaetes in the genus Polydora have been inadvertently transported worldwide as a consequence of the movement of non-native commercially important shellfish.

P1-113 RE, C*; PEREZ, J; TACDOL, A; PROTAS, M; Dominican University of California; *cas-re@hotmail.com*
The Genetics Behind Pigmentation and Eye Traits in Cave Populations of the Crustacean, Asellus aquaticus
The isopod crustacean, Asellus aquaticus, has surface and cave dwelling forms that differ in pigmentation, eye size and appendage length. There are multiple cave populations of this species that are thought to have evolved independently from the surface ancestor. We asked if two cave populations, Zelske and Planina, used similar or different genetic regions to obtain the same eye and pigment phenotypes. We already knew regions of the genome responsible for eye and pigment phenotypes in the Planina cave population; therefore, our goal was to examine the Zelske cave population and see if the same regions were responsible. We generated F2 and backcross animals with Zelske and surface individuals and genotyped them for the same regions responsible for pigment and eye loss in the Planina cave population. We found that there were associations between genotypes of all four known regions responsible for eye and pigment phenotypes in the Planina cave and the corresponding phenotypes. Therefore, it is likely that all four regions responsible in the Planina cave for eye and pigment phenotypes are also responsible for the same phenotypes in the Zelske cave. Because the same regions are responsible in both cave populations, we wondered if these regions could be responsible for advantageous traits as well as loss traits. Our next step is to ask whether the same regions that are responsible for eye and pigment loss are also responsible for elaboration of antennal characteristics. To address this question, we are phenotyping F2 hatchlings for antennal characteristics and genotyping them for the same genetic markers associated with eye and pigment traits. Ultimately, we hope to understand why the same genetic regions are responsible for eye and pigment traits in these two different cave populations.

P2-69 REAGAN, E*; YACOUB, L; MUNOZ-GARCIA, A; The Ohio State University at Mansfield ; *elizabeth.reagan39@gmail.com*
The Link Between Cellular Metabolism and Resource Allocation to Reproduction: The Role of Sirtuins in the Regulation of Organ Activity
Plasticity of size and metabolic activity of organs might drive allocation of resources to different functions, such as self-maintenance, growth, storage and reproduction. Plasticity, in turn, might be the result of changes that occur in individual cells, driven by environmental cues. The nutritional status of the cells can alter metabolic pathways via post-translational modifications, like lysine acetylation. Sirtuins, a family of protein de-acetylases, have been related with the expression of changes in the metabolic phenotype. We hypothesized that plasticity in the metabolic activity of organs will be mediated by sirtuins. We measured metabolic rates, phenotypic plasticity of organ size, and patterns of protein acetylation in different tissues, in females of the viviparous cockroach Diploptera punctata. We used adult virgin females exposed to diet switches: (1) from low quality (LQ) to high-quality (HQ), then back to LQ, in periods of 30 days; and (2) from HQ to LQ, then to HQ again, in periods of 30 days. We found differences in the pattern of acetylation between diet groups, but also between organs of females. Females fed a LQ diet showed more intense acetylation of proteins in their gut than females fed with a HQ diet, consistent with a lower activity of the organ. Overall, these results suggest tissue-specific patterns of acetylation in response to dietary regimes, patterns that are consistent with the changes observed in whole-organism metabolic rates when diets were switched. Our results also suggest that the expression of phenotypic plasticity in organ size and activity is associated with changes at the molecular level.

P2-26 REDDY, MS; Univ. of Virginia, Charlottesville ; *msr3nf@virginia.edu*
The Bird-Feeder Project: Combining Science and Poetry to Further Interdisciplinary Dialogue
Initiating and sustaining dialogue between scientists and the public remains difficult and ineffective. The resulting disengagement of the public from "real science" has proven detrimental: Media and political organizations have seized the opportunity to distance science from other disciplines, inaccurately portraying science to the layman. However, education innovation trends have supported the embracing of the intersections of creative and critical thinking as a means of successfully engaging "resilient minds." Here, I present an overview of the Bird-Feeder Project which I developed to enhance communication and dissipate the "otherness" of science; I make the shared principles of the arts and sciences physically and intellectually available to the public as a way of showing how science complements well-established ways of understanding. In the vein of free libraries and poetry bins, combinations of student-produced poetry and scientific abstracts are paired based on overlapping themes or shared ideas, printed on decorative bookmarks, which are free for the public's taking, and placed in brightly colored birdhouses specially designed for the project. For example, one of the most popular bookmarks displays the pairing of a poem describing romantic heartbreak with a research abstract detailing the link between depression and cardiovascular disease. The birdhouses' proximity to local hot spots, such as cafes and libraries, maximizes exposure to diverse readers. I incorporate the work of local high school and university students as the primary feed used to construct poem-abstract combinations and recruit my peers to edit and disseminate the birdhouses.

9-4 REEMEYER, JE*; MCDONNELL, LH; CHAPMAN, LJ; University of New Orleans, McGill University ; *jereemey@uno.edu*
Effect of lifelong versus acute hypoxia exposure on the critical thermal maximum of Pseudocrenilabrus multicolor victoriae
Hypoxia is currently an increasingly pervasive occurrence in aquatic ecosystems. As oxygen is required on a biochemical level for the survival of most animals, hypoxia can have negative effects on an animal's performance by limiting its capacity for aerobic metabolic activity. This stressor is compounded by increasing water temperatures, which decrease oxygen solubility in water and increase the aerobic metabolic rate of ectothermic organisms. Under hypoxia, some animals adjust their behavior and physiology to limit their oxygen consumption and maximize the amount of oxygen they extract from the environment. However, hypoxia exposure can also limit a fish's tolerance to higher temperatures (measured as critical thermal maximum, CT_{max}). Here, we explored the relationship between thermal tolerance and hypoxia exposure on a widespread African Cichlid, *Pseudocrenilabrus multicolor*. We reared F1 offspring of parental stock collected from Uganda in a full factorial split brood design with two treatments (hypoxia and normoxia), and measured their CT_{max} under their rearing treatment and the alternative. This allowed us to compare of the effects of short-term versus lifelong exposure to hypoxia on thermal tolerance in these fish. Our results provide further evidence of the negative effects of hypoxia on a fish's thermal tolerance under acute exposure; fish raised in normoxia had significantly lower CT_{max} values under hypoxic test conditions. Interestingly, the CT_{max} values of the fish raised in hypoxia were not significantly affected by test condition, indicating that lifelong exposure to hypoxia likely results in long-lasting developmental changes that better equip the fish for life under hypoxia, but that lower their ability to handle thermal stress.

P3-258 REESE, T*; GEORGE, S; Georgia Southern University; *georges@georgiasouthern.edu*

Juvenile Fiddler Crab and Mussel Mound Density Related to Creek Proximity in Salt Marshes

Severe weather can have a drastic effect on salt marshes. Weather patterns that bring sudden, severe changes (storms, drought) can destabilize salt marsh ecosystems. Salt marshes act as flood barriers in the face of freak storms and flooding. *Spartina alterniflora*, a tall grass often found in salt marshes, is used as protection by fiddler crabs (*Uca pugnax* and *U. pugilator*) and as a cornerstone for mussels to build mounds. Mounds increase water holding capacity in salt marshes, play an important role in recovery from droughts, and offer protection and places to eat for fiddler crabs. Because of their position in the salt marsh food web, fiddler crab population reduction or local extinction would be detrimental to other species populations (e.g. birds, blue crabs, turtles and fish). The purpose of this study is to see whether proximity to creeks affect juvenile fiddler crab density and mound density at a salt marsh in Tybee Island, GA. Three locations near a creek (mid to low-marsh), away from the creek (high marsh), and across the street from the creek (high marsh) with three 10m x 10m plots along transect lines were setup. *Spartina* height, mound size frequency distribution and juvenile fiddler crab abundance were noted during the summer months. Preliminary measurements made at two of the three locations indicate significantly taller *Spartina* close to the creek (119.2 cm) than across the street (59.2 cm) and a mean of 9 mounds near the creek and 8 mounds across the street from the creek. There were significantly more large mussel mounds (> $3m^2$ in area) near the creek (3) than away from the creek (1). We believe there is a correlation between proximity to creeks, mussel mounds, and fiddler crab density. Severe weather and anthropogenic changes thus pose a significant threat to the health of Georgia's salt marshes.

P1-236 REEVE, RE*; CRESPI, EJ; Washington State University; *robyn.reeve@wsu.edu*

Change is more than skin deep: leptin and leptin receptor expression in the immune organs of Xenopus tadpoles and juveniles

Leptin is a pro-inflammatory adipokine hormone, modulating both adaptive and innate immune responses in mammals, but its role in the immune system of other vertebrates is poorly understood. Previously, we showed that leptin has pro-inflammatory actions and stimulates splenocyte proliferation in juvenile *X. laevis*. Leptin treatment also reduces mortality in tadpoles with bacterial infections. To determine whether leptin can have direct actions on immune organs in *X. laevis*, we used *in situ* hybridization to detect long form leptin receptor (LRb) mRNA in the thymus, spleen, liver, gut, and skin of tadpoles and juveniles. In tadpoles (NF St. 56), LRb is expressed in thymus and skin melanocytes, but absent in the spleen, potentially because in the spleen are specialized melano-macrophages. Melanocytes can act as signaling centers regulating apoptosis during metamorphosis. Leptin activation of melanocytes could indirectly affect cell number in these organs through both directly and by stimulating release of αMSH. In juveniles, LRb was expressed in spleen cortex and may have a greater role in adaptive immunity at later stages. We showed using antibody staining that leptin is most concentrated in the gut and liver, indicating these tissues may be secreting it. The spleen and thymus had lower expression levels in solitary cells spread throughout the organ. In the thymus, leptin was also found in the individual melanosomes. This research suggests that leptin directly regulates immunity through activation of LRb in both tadpole and juvenile amphibians, although it may have a greater role in adaptive immunity after metamorphosis. We also show leptin may have paracrine or autocrine actions, as both leptin and LRb are expressed in larval melanocytes, a novel role for leptin in the regulation of melanocytes.

S4-7 REGA, EA; Western University of Health Sciences, Pomona, California; *erega@westernu.edu*

Visual narrative and jargon minimization in successful anatomy teaching

Human Anatomy is the most basic of prerequisites for undergraduate and graduate health science degrees. Yet for all its ubiquity and necessity, it is frequently a class known more for rote memorization of terms than true engaged learning. Two decades of consulting with the animation and film industry have yielded the author some insights about the role of visual narrative in the education of artists, a finding broadly applicable to all student understanding regardless of level. Primates are highly visual animals and human societies worldwide routinely construct narratives explaining natural and social phenomena. Leveraging this characteristic by deliberate use of constructed visual narrative fosters understanding even at the professional school level without the need for specialized jargon. The successful visual narrative will incorporate binary comparatives to underscore key points, as well as developmental and temporal sequences. In this approach, the naming of the structures is of secondary or even tertiary importance. Rendering static morphology in story form and narratively using images to drive learning results greater understanding than the image exposition/term memorization approach dominant in conventional anatomy teaching. Once a visual narrative is assimilated, then individual terms can be more readily "hung on" the erected conceptual framework. Examples from the author's work with Walt Disney Feature Animation, Dreamworks, Sony Imageworks, EA Sports and other studios will be featured.

S2-3 REGNIER, Michael*; SNIADECKI, Nathan J.; University of Washington; *nsniadec@uw.edu*

Multi-scale platforms to study the structure and functional of cardiomyocytes derived from human pluripotent stem cells

Human inducible stem cell derived cardiomyocytes (hiPSC-CMs) are rapidly becoming the cell type of choice to study development and model disease, and for high throughput screening of drugs and small molecules. The use of hiPSC-CMs has required the development of platforms and protocols to mature cells and study their structure-function. Each of these has their advantages and limitations, and together they provide information at multiple length scales. Isolated contractile proteins can be studied with motility/microneedle force assays. The properties of the sub-cellular contractile organelles can be characterized in the absence of dynamic calcium transients in apparatus with rapid solution switching. Single cell studies of hiPSC-CMs can be performed with arrays of flexible microposts to measure the contraction force while also monitoring the calcium transients. The structure-function of hiPSC-CMs can also be studied within engineered heart tissue, which are three-dimensional tissue constructs that more closely mimic the microenvironment of the native myocardium. With these multi-scale platforms, it is possible to study human disease in the dish with patient-derived cardiomyocytes or gene-edited cells that recapture the phenotype of a disease.

136-6 REHAN, SM; University of New Hampshire;
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Conserved genes regulate phenotypic plasticity in an incipiently social bee

The genetic underpinnings of social behavior are of great interest to understanding the evolution of social complexity. Genomic data for solitary and eusocial species are now available and have revealed important insights into the mechanisms of social evolution. The evolutionary path from solitary to eusocial life history likely involved intermediates, but genomic data is lacking for these species. Only by performing genomic comparisons that include the early stage social species will we truly begin to understand the genomic mechanisms underlying the transition from simple to complex societies. New data are provided on the first incipiently social bee species yet examined in depth on a genomic level. These genomic and transcriptomic data for the Australian small carpenter bee, *Ceratina australensis*, are used to empirically test hypotheses about the genomic basis of social transitions in bees. This species is of special interest because it is socially polymorphic with both solitary and social nests occurring in the same populations, and are an early stage social species. *C. australensis* provides a natural experiment to investigate the molecular changes that may underlie the transition from solitary to social life within a single species. These data demonstrate that gene regulatory changes are of primary importance relative to protein evolution in *C. australensis* sociality. Genes associated with social vs solitary nesting in this species show a clear signature of being deeply conserved and slow-evolving, in contrast to previous studies showing novel and faster-evolving genes associated with derived sociality in other bees. Gene family expansions and positive selection on zinc-finger transcription factors are noted in *C. australensis* compared to other bees. These data provide support for the idea that the earliest social transitions are driven by changes in gene regulation of deeply conserved genes.

P3-172 REHOREK, SJ*; GEORGE, JC; SUYDAM, R; MCBURNEY, DM; THEWISSEN, JGM; Slippery Rock Univ., Slippery Rock, North Slope Borough, Barrow, NEOMED, Rootstown; *susan.rehorek@sru.edu*

Whale tears: Source and Function

Orbital glands are found in many tetrapod vertebrates, and are usually separate structures: with individual glands lying in the eyelids and both canthi of the orbit. In cetaceans, however, the orbital glandular units are less distinct and have been described by numerous authors as a single, periorbital mass. It is presumed that these orbital glands produce the ocular fluid, whose primary role in cetaceans may be defense. Though histochemical data is available for only a few species, it is restricted solely to the periorbital glands, and does not mention any eyelid glands. In this study, we examined the orbital region of both a bowhead whale (*Balaena mysticetus* : Mysticeti) and a beluga whale (*Delphinapterus leucas*: Odontoceti). Both species examined possess a periorbital glandular mass, which have slightly larger masses in the rostral (Harderian) and cranial (lacrimal) poles. The bowhead whale also possessed a smaller glandular mass in the middle of the upper eyelid (glands of Wolfring) and a series of diffuse glandular units in the rim of the eyelid (Meibomian glands). Histochemically all bowhead whale orbital glands possess the same four distinct secretions. However these glands exhibit differences in glandular activity level, density of glandular material and presence of Pacinian corpuscles. Beluga orbital glands additionally possessed lipid granules, but lack the Pacinian corpuscles. Despite this histochemical homogeneity, there is chemical heterogeneity between the glands, specifically in the form of regionalized bactericidal agents. This is the first time such chemical heterogeneity has been shown in orbital glands of any tetrapod.

P1-198 REID, KA*; BLOOMQUIST, ER; TOBALSKE, BW; POWERS, DR; George Fox University, Newberg, OR, University of Montana, Missoula, MT; *kreid15@georgefox.edu*

Are hummingbird bills used in thermoregulation during hovering?

Birds generate large amounts of heat during flight due to low mechanical efficiency of their flight muscles. At moderate temperatures hummingbirds dissipate excess heat generated during flight through heat dissipation areas (HDAs) around the eye, shoulder, and feet. However, because HDAs depend on thermal gradients they may be ineffective at higher temperature. Some birds with larger bills radiate heat from their bills as a supplemental form of heat dissipation; the bill is potentially ideal for convective heat dissipation during flight because it experiences high dynamic pressures In this study we used infrared thermography to determine if hummingbirds used their elongated bills for supplementary heat dissipation during flight, and if this might be a means of compensating for loss of a thermal gradient at high temperature. We measured variation in bill surface temperature of calliope hummingbirds (*Selasphorus calliope*; 2.5g) flown in a wind tunnel at 0-8 m/s (23°C) and 0 m/s (38°C) to determine if the bill could radiate heat. At both 23° C and 38°C bill surface temperature declined from the proximal to distal end of the bill. At 23°C the bird's bill surface temperature was 3-7°C higher than that of ambient temperature, with highest temperatures near the proximal end of the bill. The favorable gradient thermal gradient between bill surface temperature and ambient temperature could indicate a thermoregulatory function for the bill at lower temperatures. At 38°C bill surface temperature did not differ from ambient temperature suggesting no thermoregulatory function at higher temperatures.

5-1 REIDENBACH, MA*; MURPHY, EAK; STOCKING, JB; University of Virginia; *reidenbach@virginia.edu*

Hydrodynamics of Algal Biofilms

Algal biofilms are common fouling organisms on natural and man-made aquatic surfaces, and have a major impact on diverse systems ranging from corals, where they impede essential exchange of gases and particulates, to ship hulls, where they induce severe drag penalties while ships are in motion. Biofilms themselves have great diversity, but typically are algal or bacterial cells embedded in exocellular polymeric substance (EPS), and behave as a viscoelastic solid. When biofilms grow under hydrodynamic stress, they form thin, flexible streamers that protrude into the flow. Because biofilms typically form a compliant surface with protruding streamers, interactions between biofilms and hydrodynamics are complex and poorly understood. Here, we describe multiple studies of the effects of algal biofilms on hydrodynamic processes occurring over both natural and man-made surfaces to determine how morphologic variability in the algal community impacts turbulent flow, surface shear, and the exchange of gases and particulates. These studies include flows over corals, intertidal mudflats, and ship hulls. Findings suggest that hydrodynamic forces can result in spatially heterogeneous formation of biofilms, leading to patchy coverage. These biofilms, even with sparse, thin coverage, is shown to increase turbulence and Reynolds shear stresses above the canopy, but can substantially reduce exchange of gases and particulates at the attachment surface.

P1-158 REIMCHE, JR*; DEL CARLO, RE; BRODIE JR, ED; LEBLANC, NM; FELDMAN, CR; University of Nevada, Reno, Utah State University ; *reimchej@gmail.com*

Predictability of Adaptive Traits: The Mystery of TTX-Resistance in the Sierra Garter Snake (Thamnophis couchii)

The convergent evolution of tetrodotoxin (TTX) resistance in garter snakes (*Thamnophis*) has shown remarkable predictability. Patterns at both the phenotypic and genetic level have been consistent across multiple *Thamnophis* species throughout North America, implying that there may be strong molecular constraints involved in this adaptive trait. To further examine the predictability of TTX-resistance, we studied patterns of resistance in the Sierra Garter Snake (*Thamnophis couchii*). To characterize the phenotype, we quantified TTX resistance at both the whole animal and skeletal muscle levels. We then determined patterns of functional genetic variation in these snakes by genotyping three sodium channel genes ($Na_v1.4$, $Na_v1.6$, and $Na_v1.7$) that are the molecular targets of TTX, and that display important amino acid replacements known to confer TTX-resistance in snakes. Finally, we measured expression levels in one of these genes ($Na_v1.4$), known to be a locus of major effect in other *Thamnophis* species. We found that *T. couchii* demonstrate high variation in phenotypic TTX-resistance, despite possessing identical amino acid sequences in all three genes (that is, each gene is fixed for a single allele). Furthermore, we found no differences in gene expression in our candidate locus between TTX-resistant and TTX-sensitive snakes. Currently, resistance cannot be explained by a relationship between Na_v genotype and phenotype. These results suggest that there are additional loci or other genetic mechanisms involved in TTX-resistance in *T. couchii* and that TTX-resistance may not be as predictable as previously thought.

60-7 REINKE, BA*; LAWING, AM; Texas A&M University; *elizabeth.a.reinke@dartmouth.edu*

The Evolution of Wing Colorfulness in a Butterfly Group

Signal diversity is driven by a variety of selective pressures such as predation and mate recognition. In butterflies, the ventral and dorsal wing surfaces are generally under separate and sometimes opposing selective pressures. We collected reflectance spectra for color patches on the dorsal and ventral wings of individuals in the lepidopteran group *Lycaena*. We then plotted these colors within a trichromatic and tetrachromatic color space to model the relative stimulation of cones in conspecific and heterospecific (avian) predator visual systems, respectively. We estimated the volume of occupied color space, the average hue disparity, and the color richness to obtain measures of colorfulness and, using phylogenetic comparative methods, we compared the rates of color and contrast evolution for both wing types. We tested the best fit model of evolution for each wing type, considering Brownian motion, Ornstein-Uhlenbeck, diversifying selection and white noise. By comparing the results between color spaces and wing types, we can infer the relative strength of natural and sexual selection on wing surfaces as well as the role of sensory systems in the evolution of signals.

P2-248 RENN, SCP*; COYLE, KP; ROBERTS, NB; ROBERTS, RB; Reed College, Portland OR, N.C. State Univ., Raleigh, NC; *renns@reed.edu*

The Intestinal Environment as an Evolutionary Adaptation to Mouthbrooding in Astatotilapia burtoni: Cell Turnover and Microbiome

Female *Astatotilapia burtoni*, a species of mouthbrooding cichlid, voluntarily starve themselves for two weeks while their young develop. Little is known about the physiological mechanisms that have evolved to allow them to accomplish this. A. burtoni therefore represent an excellent animal model in which to study the mechanisms that integrate the regulation of feeding and reproduction. Brooders who are starving face different challenges than starving non-brooders; by comparing brooding and starved females, we aim to identify key evolutionary innovations that allow for mouthbrooding. In addition to the neural regulation of feeding, peripheral changes in physiology are also necessary to allow brooders to conserve energy. Preliminary RNAseq data suggest that gut cell turn over, an energetically expensive process, may be regulated throughout the brooding cycle in a manner that differs from a female that is simply starving involuntarily. Imunohistochemical techniques to detect cell proliferation and apoptosis in the intestines support this finding. We show fewer apoptotic cells in brooding females compared to starved or fed females. These physiological differences in the gut will create a novel environment that may feedback on the behavior and physiology of the brooding female. Here we track the gut microbiota of female cichlid to discover changes associated with brooding stage. Such studies may reveal interaction between host and microbiome that could influence this key evolutionary innovation of mouth brooding.

P2-249 RENN, SCP; O'MALLEY, T*; GRAY, M; Reed College, Portland OR, Madison High School, Portland OR; *renns@reed.edu*

An Arduino based robotic system to quantify Brood Care Motivation in the mouth-brooding cichlid A. burtoni.

Female *Astatotilapia burtoni*, a species of mouthbrooding cichlid, voluntarily starve themselves for two weeks while their young develop. Little is known about the physiological mechanisms that have evolved to allow them to accomplish this. *A. burtoni* therefore represent an excellent animal model in which to study the mechanisms that integrate the regulation of feeding and reproduction. Females with broods in their mouths do not feed, even if the brood is removed from the buccal cavity. This suppression of appetite, termed brood care motivation (BM), has previously been measured as the reduction in the quantity of food a female will consume. Here we develop an Arduino-based robotic system for the automatic quantification of brood care motivation in the mouth-brooding African cichlid *A. burtoni*. This advance will eliminate the consummatory act of feeding in the process of quantifying brood care motivation and allow us to investigate the underlying neural and physiological mechanisms. The Arduino-based system is routinely used for teaching-robots in High School education, these experiments offer the opportunity for outreach and collaboration.

P1-102 RENNOLDS, C*; BELY, AE; Univ. of Maryland, College Park; *rennolds@umd.edu*

Functional Consequences of Tissue Loss and Regeneration in the Annelid Pristina leidyi

The ability to regenerate lost body parts is widespread but variable in animals, and organismal physiology is expected to contribute significantly to regeneration success. Annelids, the segmented worms, include many regenerators, but little is known about how tissue loss and regeneration affect other life processes such as reproduction or environmental stress resistance. The annelid *Pristina leidyi* reproduces asexually via paratomic fission, making it a convenient organism in which to study investment strategies and functional consequences of regeneration. I am studying how the loss and subsequent regeneration of tissues alters the response of *P. leidyi* to thermal stress and reproductive investment, including how these responses differ depending on the specific tissues lost, i.e. head vs. tail segments. To determine the impact of tissue loss and subsequent regeneration on thermal resistance, I am assessing how survival and metabolic rate are affected by acute thermal exposure both immediately after amputation and after regeneration is complete. For this project, I am also assessing cellular and energetic allocation patterns during regeneration and how allocation strategies affect reproductive output. Understanding the functional costs of tissue loss and regeneration, and how these costs vary depending on extrinsic and intrinsic conditions, will contribute to understanding what factors may influence regeneration success and investment. Ultimately, such studies will improve our understanding of the evolution of regeneration and how changing environmental conditions may impact ecological processes involving regenerating species.

P3-130 REP, M.A.*; JACOBS, M.W.; BAYER, S.; McDaniel College, University of Maine - Darling Marine Center; *mar017@connections.mcdaniel.edu*

Intraspecific competition of juvenile green crabs (Carcinus maenas) depending on predator population density and resource availability

The European green crab (Carcinus maenas) was introduced to the Gulf of Maine in the 1800's and has since then populated a large proportion of the East Coast. It is understood that a higher density of conspecific predators leads to higher levels of intraspecific competition. Factors such as size of competitors, habitat, and prey density also play a role. However, little is known about conspecific competition of juvenile green crabs specifically, and what resource they prioritize (food vs. shelter). This study aims to better understand intraspecific competition of juvenile green crabs in the Damariscotta River based on competitor density and resource availability. Lab experiments were conducted during the summer of 2017 at the Darling Marine Center. Small (5-10mm) and large (20-25mm) juvenile crabs were placed in artificial settings in either low or high density treatment, as well as with limited or abundant shelter treatment. The proportion of time foraging, sheltering and eating was recorded and analyzed. It is hypothesized that a) smaller crabs will prioritize shelter over foraging, and b) crabs in higher densities will spend less time foraging than those in lower density. Finally, I expect individuals with abundant shelter space to prioritize foraging. Preliminary results show crabs, regardless of size, spend more time foraging than hiding. In higher densities, this remains true. However, when shelter is abundant, larger crabs spend more time hiding than foraging, which is contrary to the behavior of smaller crabs. Once all data has been analyzed, this study aims to inform about the intraspecific dynamics of juvenile green crabs, which may contribute to better understanding the population dynamics of this species.

P1-214 RESNER, EJ*; MARSH, K; GILBRETH, N; BONSALL, K; KUMRO, MB; HARDY, KM; California Polytechnic State University; *eresner@calpoly.edu*

RESPIRATORY BEHAVIORS AND OXYGEN CONSUMPTION RATES DURING AIR EXPOSURE AND ENVIRONMENTAL ANOXIA IN THE GIANT ACORN BARNACLE, BALANUS NUBILUS

The giant acorn barnacle, *Balanus nubilus*, has the largest muscle fibers in the animal kingdom (diameters can be > 3mm in adults). At these sizes, muscle cells are at risk for insufficient oxygen delivery owing to low SA:V ratios. This challenge may be exacerbated during low tide air emersion or environmental hypoxia, when hemolymph oxygen levels are predicted to drop. Barnacles, however, are particularly successful at acquiring oxygen and maintaining similar rates of aerobic metabolism under both aquatic *and* terrestrial conditions. We are interested in whether *B. nubilus* possesses these abilities given the potential metabolic limitations of their giant muscle fibers. We investigated the respiratory behaviors (% time aperture open, cirri beat frequency) of *B. nubilus*, during acute (6h) exposure to normoxic immersion, air emersion, and anoxic immersion. Further, we compared oxygen consumption rates (MO_2; via intermittent respirometry) of barnacles in water (10, 15, 20°C) and in air (15, 20°C). Preliminary data revealed that *B. nubilus* have a significantly higher cirri beat frequency and % time aperture open (with cirri extended) during normoxic immersion than anoxic immersion, though these values are not significantly different from animals held in the air. This suggests that *B. nubilus* does engage in behaviors aimed at increasing oxygen uptake while out of the water, but remains relatively inactive during anoxia. Based on this, we predict that MO_2 values for *B. nubilus* will be similar in water and air. To date, we have found a significant linear relationship between temperature and MO_2 in the aquatic realm - as we would expect for an ectotherm - and we are still collecting our terrestrial MO_2 values.

P3-152 REUTTER, M*; BAKIASI, G; BONNER, E; FREDERICK, J; SPIEGEL, E; OKUMURA, M; DAVIS, GK; Bryn Mawr College; *mreutter@brynmawr.edu*

Local adaptation of the pea aphid photoperiod response

As reproductive mavericks, aphids do not conform to a single mode of reproduction. Instead, species such as the pea aphid, *Acyrthosiphon pisum*, typically alternate between viviparous parthenogenesis in the spring and summer, and oviparous sexual reproduction in the fall. In the latter case, eggs produced by sexual females are frost-resistant, allowing a population to overwinter. Reproductive fate (asexual vs. sexual) is specified pre-natally, during embryogenesis, by the mother in response to photoperiod—in particular, short nights specify asexual fates while long nights specify sexual fates. Juvenile Hormone (JH) likely mediates this process, as JH titer correlates with photoperiod and topical application of JH can induce asexual fate, even under long nights. Populations also have the ability to adapt to geographical variation in the timing of the first frost through modification of the photoperiod response. For example, southern populations that experience frost later in the season are induced by longer nights, manifesting as a delay in the production of sexuals and eggs. At the extreme, more southerly populations that are unlikely to see a winter frost may not produce sexuals at all. Here we address the role of JH in the photoperiod response and describe differences in the response between pea aphid populations from the Northern and Southern United States. We also test at least one hypothesis for the evolution of the photoperiod response by examining JH sensitivity and the expression of genes in the JH pathway.

127-4 REYES, ML*; BARBOSA, J; PARKER, B; GERARDO, N; Emory University, University of Rochester; *miguel.l.reyes@emory.edu*

Impact of temperature, morphology and symbionts on aphid reproduction and survival

Much is known regarding the impact of global climatic shifts on the stability of insect communities. However, the influence of rising temperatures on host-microbe interactions and their influence on reproduction is less understood. Pea aphids (*Acyrthosiphon pisum*) asexually produce offspring with distinct winged and wingless phenotypes when exposed to environmental stressors. Besides harboring the obligate bacterial symbiont, *Buchnera aphidicola*, which provides essential amino acids, some pea aphids can establish and maintain "secondary" facultative symbionts such as *Regiella instecticola*, which can provide protection against fungal pathogens. While winged and wingless individuals from the same mother are genetically identical, additional energy is required for wing production and maintenance. Such energy needs may be further impacted by the presence of secondary bacterial symbionts. By inducing production of winged offspring via crowding, and further exposing winged and wingless adults to heat-shock, we assessed the influences of heat stress, morphotype and secondary symbionts on reproductive ability and lifespan. Morphotype and stress treatment, but not symbiont status, significantly impacted aphid reproduction: winged, unstressed aphids reproduced more than their wingless sisters. In contrast, all three factors impacted survival, with symbiont status having the strongest source of effect: aphid lines containing fungal-protective *Regiella*, in addition to those without the secondary symbiont had the highest levels of survival. Our results suggest that upon environmental stress, morphotype is the main driver for adaptation. Furthermore, the energy spent on maintaining protective secondary symbionts may result in a tradeoff with decreased reproduction and overall lower life quality upon the absence of the pathogen.

85-7 REYNAGA, CM*; EATON, C; STRONG, G; AZIZI, E; Univ. of California, Irvine, Colby College; *reynagac@uci.edu*

Hindlimb mechanics and motor pattern response to varying compliant substrates in the Cuban tree frog

Arboreal frogs navigate complex environments and face various changes in mechanical properties of the physical environment. Changes in substrate compliance and elasticity can pose challenges when jumping off structures like leaves or thin branches. An optimal, well-coordinated jump will allow the recovery of elastic energy stored in a springy substrate to amplify mechanical power by effectively adding an in-series spring to the hindlimbs. However, in a poorly coordinated jump the energy applied to the substrate is not recovered. The effective utilization of such springy substrates requires changes in the timing of muscle activation to allow energy recovery. We investigate the effects of substrate compliance on the hindlimb kinematics and motor control patterns during jumping in Cuban tree frogs (*Osteopilus septentrionalis*). We designed an actuated force platform, modulated with a real-time feedback BeagleBone controller to vary the stiffness of the substrate. We quantify the kinetics and kinematics of tree frogs jumping-off platforms at four different stiffness conditions. Additionally, we surgically implanted two EMGs in a knee extensor, the *cruralis*, and an ankle extensor, the *plantaris*, to examine the relationship between muscle activation patterns and substrate compliance during take-off. We find tree frogs do not modulate motor patterns or kinematics in response to substrate compliance. These results highlight a potential trade-off in amplified systems between jump performance and responsiveness in animals that rely on elastic mechanisms to amplify power. This work serves to broaden our understanding of how the utilization of elastic energy may alter the responsiveness of an organism to react to perturbations.

P3-112 RICE, A*; FUSE, M; San Francisco State University; *arice4@mail.sfsu.edu*

The Cockroach Neuropeptide, Leucopyrokinin (LPK), Inhibits Sensitization in the Tobacco Hornworm, Manduca sexta

LPK is a cockroach native neuropeptide apart of the PBAN/pyrokinin peptide family. When injected into mice, LPK induces antinociception mediated through opioid receptors. Regardless of sequence and structure differences to vertebrate opioid peptides, LPK is able to bind to vertebrate opioid receptors. The belief is invertebrates also possess opioid like receptors because they possess opioid-like peptides such as enkephalins. Thus, I hypothesized that LPK will also induce antinociception mediated by opioid-like receptors when injected into *M.sexta* as similarly seen in mice. In order to test LPKs effect on antinociception in invertebrates the peptide was injected in *M. sexta* and then provided with a noxious stimulus. A range of low to high force filaments were used until animals exhibited their defensive strike response. Our results showed that the active fragment [4-8] LPK inhibited sensitization of the defensive strike response in a dose response manner. To complement my study I will test the effects of [4-8] LPK with the addition of vertebrate opioid receptor antagonist, naloxone to determine the involvement of opioid receptors in inhibiting sensitization. The *Manduca sexta* genome will also be searched for opioid receptors using bioinformatics. Our results will suggest the conservation of vertebrate opioid receptors in *Manduca sexta*.

100-1 RICHARDS, CT*; EBERHARD, EA; Royal Veterinary College; *ctrichards@rvc.ac.uk*

A jumping frog musculoskeletal simulation powered by living muscle tissue

In vitro measurements reveal important muscle properties, yet their implications for animal performance are not obvious. How does neural stimulation affect jump performance? How do evolutionary transformations in skeletal anatomy influence neural control requirements? Current experimental tools are inadequate for these questions because they do not measure a muscle's interactions with the skeleton and locomotor substrate. We used a novel technique interfacing an *in vitro* muscle with the ankle joint of a frog simulation containing hip, knee, ankle and TMT joints. Custom electronics transmitted *in vitro* force to a physics engine (MuJoCo) performing joint and ground contact dynamics in a PC. At 1 kHz, *in silico* muscle length was transmitted to update *in vitro* muscle length enabling the 'real world' muscle to behave as if attached to a 'virtual reality' skeleton whose anatomy and inertial properties were determined in software. We addressed the above questions by manipulating muscle stimulation as well as limb anatomy. The activated muscle enabled jump velocities comparable to real frogs. Advancing stimulation by 10 ms intervals (hip and knee control unchanged) caused steeper takeoff angles with speed unaffected. Additionally, manipulating the muscle's bi-articular action at the knee limited muscle shortening, but enhanced power output by a mechanism not yet understood. Further experiments with this technique will be used to explore how dynamic and transient interactions with inertial loads and ground contact affect muscle mechanics and jumping performance.

P2-80 RICHARDS, HM*; WATSON, CM; Midwestern State University; *hannahmrichards@yahoo.com*

Digestive Efficiency and Physiology of the Texas horned lizard (Phrynosoma cornutum) in North Texas

The Texas Horned Lizards (*Phrynosoma cornutum*) is a threatened species due to widespread habitat loss, urbanization, and the decline of their primary prey, harvester ants (*Pogonomyrmex sp*). These ants experience declining populations due to overuse of pesticides and the spread of red imported fire ants (*Solenopsis invicta*). With its primary prey source in decline, these lizards may supplement their diet with a variety of beetles as a small, but consistent part of their diet. We determined the diversity of available prey by setting pitfall traps in a known Texas horned lizard habitat in North Texas. We determined diet composition by dissecting Texas horned lizard fecal samples found in the study site. We then compared digestive efficiency of horned lizards fed solely harvester ants and solely beetles using bomb calorimetry. Although many potential prey items were available, only harvester ants and beetles were constantly found in fecal samples. Harvester ants made up over 90% of the diet, but remnants of small beetles were found in all samples. Other groups, such as bees and weevils were periodically found, but were rare. Although they make up most of the lizards' diet, they are unable to digest ants efficiently (~30%). The digestive efficiency with beetles was variable but significantly higher. Therefore, the lizards may be selecting beetles to negate nutritional deficits that may result from an all-ant diet.

P2-205 RICHARDS, LM; LEVINE, KK; RIVERA, G*; Creighton Univ.; *gabrielrivera@creighton.edu*

The effects of foreleg loss on locomotor performance in the darkling beetle Zophobas morio

Limbed locomotion requires the coordinated movement of limbs to produce maximal performance, but what are the consequences of limb loss on locomotor strategy and efficiency? Quadrupedal animals that lose a limb must alter their kinematic patterns to maintain the ability to locomote. While animals with more limbs should be less severely impacted by the loss of a single limb, their locomotor performance may similarly be enhanced by modulation of kinematic patterns. Do animals always modulate kinematic patterns? Will animals in similar situations converge on a single, optimal answer? To address these questions, we examined the effects of foreleg loss on locomotor performance in the darkling beetle *Zophobas morio*. We collected data on locomotor performance (distance traveled per limb cycle and locomotor speed). We also used GMM techniques and multivariate analyses to investigate the position and timing of footfalls during stance. Data were collected from beetles under three conditions: (C) control, unaltered beetle; (RA) right after, data collected on the day of limb removal, and (LA) long after, data collected a week following limb removal. While leg loss did not impact the distance that beetles traveled over a full limb cycle, there was a significant decrease in speed between the control treatment and the two experimental treatments. Following leg removal, experimental beetles altered the position and timing of foot placement for the remaining five legs. However, immediately following leg removal (RA), beetles displayed foot placements more similar to control treatments and these patterns diverged more with time (LA). In addition to differences in foot position, we also found that variation in foot position increased with time, presumably as individuals identify different strategies that help to produce more stable locomotion.

107-6 RICHARDSON, EL*; ALLEN, JD; College of William & Mary; *elrichardson01@email.wm.edu*

The road to stardom: linking larval food environment with juvenile recruitment success in echinoderms

Echinoderms are characterized by boom-bust population dynamics in which species exhibit rapid outbreaks followed by drastic die-off events. These extreme density fluctuations can be driven by both bottom-up (e.g. prey availability) and top-down (e.g. predator presence) forces, and recruitment bottlenecks may occur at a variety of life history stages (e.g. poor fertilization, high larval mortality, etc.) However, few studies have considered the importance of links between life history stages, particularly the potential role larval history has in impacting juvenile recruitment dynamics of echinoderms. Laboratory studies of the sea star *Asterias forbesi* have shown that larvae reared on low food concentrations have lower survival to settlement and metamorphose as smaller juveniles with fewer protective spines than those reared at high food concentrations. We extended these studies to test how differing levels of phytoplankton concentration during *A. forbesi* larval development impacts post-metamorphic juvenile performance and whether juveniles with access to high levels of food can overcome the negative effects of low larval food background. We manipulated food availability during larval rearing (two levels: high = 22,500 cells ml^{-1} or low = 7,500 cells ml^{-1}) and during juvenile rearing (four levels: fed 6 juvenile mussels $week^{-1}$, 3 juvenile mussels $week^{-1}$, 1 juvenile mussel $week^{-1}$ or unfed) to assess the relative importance of feeding in each life history stage. Our response variables were juvenile survival and growth, number of juvenile mussels eaten $week^{-1}$ and mean size of juvenile mussels eaten. We then compared the effects of larval food availability with juvenile food availability to determine whether pre- or post-metamorphic processes have a greater impact on sea star growth and survival.

P1-83 RICHTER, MM*; ASHLEY, NT; Western Kentucky University; *melanie.richter@wku.edu*

Making Hay While the Sun Shines: How an Arctic-breeding Songbird Copes With 24 Hours of Daylight

In Barrow, Alaska (71.2906° N, 156.7886° W) the sun rises on May 10 and does not set again until August 2. This constant light can influence the activity patterns of the animals present; some animals "free-run" with no discernable circadian activity patterns, while a few species are able to maintain a circadian rhythm despite the lack of darkness. One species thought to fall into this latter category is the Snow Bunting (*Plectrophenax nivalis*), a small songbird that migrates to the high Arctic to breed each summer. To elucidate the activity patterns of this species, we utilized accelerometers that record movement in all 3 axes every second. Eleven adult males outfitted with these accelerometers were housed in an outdoor aviary where they were exposed to natural light and temperature cycles for up to 6 days. Males were able to maintain an activity pattern despite constant light. We also attempted to manipulate sleep in this species by implanting males with melatonin or empty silastic capsules to determine whether supplementation affects paternal care. We banded and tracked males to their nests and then performed feeding observations, nest checks, and monitored nestling growth to determine whether males given melatonin were poorer providers than controls. There were no differences in the feeding rates (Control: 6.3, Melatonin 5.7, p=0.39), or in mean hatchling weight at 3 different time points (2d post-hatch: C:7.0, M: 6.7g, p=0.4; 4-5d post-hatch: C: 12.9, M: 13.5g, p=0.4; day 6-7 post-hatch: C:22.5, M: 21.1g, p=0.35). While a preliminary study, our current results indicate that despite snow buntings maintaining circadian rhythmicity, they seem to be insensitive to melatonin implants when feeding nestlings

130-6 RICO-GUEVARA, A*; HURME, KJ; Univ. of California, Berkeley, University of Connecticut; *a.rico@berkeley.edu*
Intrasexually Selected Weapons
We propose a practical concept that distinguishes the particular kind of weaponry that is used specifically during same-sex combats, which we term "intrasexually selected weapons" (ISWs). We offer hypotheses to answer the question: Why only some species have evolved weapons to fight for the opposite sex? We examined traits that seem to have evolved as ISWs in the entire animal phylogeny, restricting the classification of ISW to traits that: are only present or enlarged in one of the sexes, do not appear or enlarge until adulthood, and are used as weapons during intrasexual fights. We found that ISWs are only found in bilateral animals; appearing independently in nematodes, arthropods, and vertebrates. We establish that most ISWs: come in pairs, are located in or near the head, are overdeveloped structures of those found in females, are endo- or exoskeletal modifications, are modified feeding structures and/or locomotor appendages, are frequently used to guard females, territories, or both, and are also used in signaling displays to deter rivals and/or attract females. We also found that most taxa lack ISWs, that females of only few species possess better-developed weapons than males, that the independent evolutions of ISWs are not evenly distributed across the animal phylogeny, and that most vertebrates possessing ISWs have non-hunting habits (e.g. herbivores), or are carnivores that prey on very small prey relative to their body size (e.g. insectivores). We provide an evolutionary flow chart for ISWs and discuss biomechanical rationales not only for the appearances but also for the fashioning of the weapons. We provide a case study, with hummingbirds, linking functional morphology and performance measurements both of combat abilities and the relevant biological function affected by the ISW.

29-2 RIDDELL, EA*; CARLO, MA; BALDWIN, RF; ZAMUDIO, KR; SEARS, MW; University of California, Berkeley; *riddell@berkeley.edu*
Using physiology to predict habitat suitability during the last climatic oscillation: implications for conservation
Extinction rates remained stable during major climatic fluctuations in Earth's recent past, yet current ecological models predict rapid reductions in biodiversity under future warming. The capacity of populations to withstand climatic oscillations likely depended upon the shifting spatial structure of suitable habitat, the velocity of climate change, and the dispersal capacities. By modeling the fundamental niche and dispersal through climatic change, ecological models can identify the mechanisms that promote population persistence during climatic fluctuations. We integrated a physiologically-structured species distribution model with a dispersal model to determine mechanisms underlying range dynamics in past and future climates in the global hotspot of salamander diversity. Our results indicated that plasticity in the phenology buffers populations from extinction during historic climate change, and current species ranges are structured by dispersal capacities and climate velocity in the recent past. We also suggest that historic distributions of the fundamental niche and dispersal capacities supported long distance colonization events that influenced genetic variation across southern Appalachia. We conclude by identifying specific habitat needed to maintain a global hotspot of diversity during climatic change to inform ongoing conservation efforts.

P1-101 RIDDELL, EA*; ROBACK, E; ZAMUDIO, KR; WELLS, CE; DAMM, J; SEARS, MW; University of California, Berkeley; *riddell@berkeley.edu*
Functional genomics underlying variation in thermal acclimation of water loss rates in a salamander
Reversible acclimation represents a universal strategy among organisms that reduces stress from the environment. Dehydration stress threatens terrestrial taxa by directly reducing performance or constraining durations of foraging and reproductive activities. Organisms can avoid dehydration stress by reducing water loss rates; however, we know very little on the capacities of organisms to adjust water loss rates and the environmental cues that elicit acclimation of water loss rates. We conducted an acclimation experiment to evaluate the capacity of a terrestrial salamander (*Plethodon metcalfi*) to adjust rates of water loss in response to cycling temperature and humidity treatments as cues for acclimation. Our experimental design controlled for the evaporative demand of the air by adjusting relative humidities with the cycling temperatures to explicitly test temperature and humidity as cues for acclimation. Then, we monitored changes in skin resistance to water loss over the course of four weeks in the acclimation study using a flow through system. After the final measurements, we sacrificed the individuals and extracted total RNA from skin tissue. From these samples, we constructed a *de novo* transcriptome and performed a differential gene expression analysis. The experiment revealed that salamanders acclimated to temperature, and individuals exhibited variation in acclimation response in which individuals either lowered water loss rates during the experiment or they maintained low water loss rates throughout the entire experiment. Our differential gene expression analysis identifies potential networks of genes that explain variation in acclimation capacities. These potential regulatory networks might provide a basis for predicting acclimation responses to environmental stressors, such as warming temperatures.

P2-217 RIDGE, NC*; CIERI, RL; FARMER, CG; University of Utah; *nicholas.c.ridge@gmail.com*
Computational Simulation of Pulmonary Airflow in Pogona vitticeps (Bearded Dragon)
Unidirectional flow is a respiratory condition where air flows through parts of the lung in the same direction during both inspiration and expiration. Although it was once generally thought that unidirectional airflow arose after the development of endothermy in birds, in response to increased metabolic needs, recent research has provided evidence of unidirectional airflow in crocodilians, iguanas, and varanid lizards, suggesting an alternative evolutionary history. A powerful method to explore pulmonary airflow patterns is the use of computational fluid dynamics (CFD) modeling. To gain insight into patterns of airflow in other lepidosaurs, a CFD model was developed to simulate convective airflow in the respiratory system of the bearded dragon (*Pogona vitticeps*) using the following methods: The anatomy was captured mathematically on a live, anaesthetized animal using computed tomography (CT). The CT scans were then visualized in Osirix. Avizo was used to segment the CT scans and generate a smoothed, high-fidelity computational mesh of the right lung. This high-fidelity computational mesh was then subjected to a series of simulations in OpenFOAM, including steady-state inhalation, steady-state exhalation, and dynamic respiration. Boundary conditions were set according to physiological data of Bearded Dragon respiration. Pressure at the outlet was set to 0 kPa and the inlet velocity was calculated based on published values of breathing frequency, inspiratory and expiratory duration, and from the following scaling relationship for tidal volume (V_T) : $V_T = aM^{0.75}$. The mass of the specimen studied was 330 g. Inlet velocity was determined to be 5.47E-7 cm^3/s. The solved simulations were visualized and processed using ParaVIEW software.

32-4 RIEGER, NS*; MARLER, CA; Univ. of Wisconsin; *nrieger@wisc.edu*

Oxytocin Induces Sex-Specific Changes in Territorial Defense by Pair-Bonded California Mice

Monogamous pair bonding allows for division of labor and coordination of complex social behaviors within a pair. While oxytocin (OT) influences formation and maintenance of pair bonds in monogamous species, its role in division of labor and territorial defense by pair-bonded individuals is unknown. We studied OT's role in territorial defense by pair-bonded California mice (*Peromyscus californicus*). Previously we found that resident pairs of California mice use either male only or female only divided defense or joint defense against territorial intruders, with pairs maintaining a single strategy across varied conditions. To elucidate the role of OT, we administered an intranasal dose (0.8 IU) of OT to either both members of the pair or only the male or female of the pair 5-min prior to a territorial intrusion. OT revealed sex specific differences in defense coordination and vocal communication (ultrasonic vocalizations) during territorial intrusions. When females but not males, received OT, pairs were more likely to divide defense (Female; OT: 61%, Saline: 36%), and females were more likely to act as the defender than in any other condition (Female; OT defenders: 85%, Saline Defenders: 50%). When males but not females, received OT, call duration was shortened (Male; OT: 112 ± 9.9 ms, Saline: 298 ± 31 ms). When both individuals received OT, pairs both increased divided defense (Both OT: 61%, Saline: 36%) to female only levels and shortened calls (Both OT: 197 ± 27 ms, Saline: 298 ± 31 ms) to male only levels. Overall, hormone administration revealed that OT induced greater behavioral plasticity in defense in females, while inducing greater behavioral plasticity in ultrasonic vocalizations in males, illustrating a sex specific role for oxytocin in territorial defense. (NSF Grant IOS1132419)

P3-55 RIFAI, N M*; DAS, S; MYKLES, D L; Colarodo State University; *nadarifai2008@yahoo.com*

Transcriptomics of Cyclic Nucleotide Phosphodiesterase Gene Expression in the Decapod Crustacean Molting Gland

Cyclic nucleotides mediate the repression of the crustacean molting gland (Y-organ or YO) by molt-inhibiting hormone (MIH). When MIH levels decline, the YO transitions from the basal to the activated state and the animal enters premolt; this transition requires mTOR. During mid-premolt, the YO transitions to the committed state, in which the YO becomes insensitive to MIH. Cyclic nucleotide phosphodiesterases (PDEs) convert cAMP and cGMP to AMP and GMP, respectively, and therefore can modify the response of the YO to MIH. Transcriptomics was used to quantify the effects of molt induction by multiple limb autotomy (MLA) or eyestalk ablation (ESA) ± mTOR inhibitor rapamycin on expression of PDE 1, 2, 4, 5, 7, 9, and 11 in *Gecarcinus lateralis* YO. In response to MLA, all seven PDEs were expressed at their highest levels in the intermolt YO. mRNA levels declined during premolt and reached their lowest levels in postmolt. In response to ESA, the mRNA levels of PDE 1, 4, 5, 7, 9, and 11 showed no significant change by 7 days post-ESA. Rapamycin had no significant effect, as PDE mRNA levels were similar to those of controls at all time points, indicating that PDE expression is not regulated by mTOR. The data suggest that transcriptional regulation does not contribute the reduced sensitivity of the committed YO to MIH; the increased PDE activity during mid and late premolt is likely regulated post-transcriptionally. Supported by NSF (IOS-1257732).

140-4 RIND, K; RODRIGUEZ-BARRUCG, Q; NICOLAS, D; CUCCHI, P; LIGNOT, J-H*; University of Montpellier, France, La tour du Valat, France; *jehan-herve.lignot@umontpellier.fr*

Morphological and physiological traits of the Mediterranean sticklebacks living in the Camargue wetland (Rhone river delta).

Salinity acclimation capacities of southern three-spined sticklebacks (Gasterosteus aculeatus L.) living in different saline habitats of the Camargue area (Rhone delta, northern Mediterranean coast) were investigated. Individuals from lagoons with different salinity ranges and from freshwater canals were exposed to seawater (SW; 30 ‰), brackish water (BW; 15 ‰), or freshwater (FW; 5 ‰). Morphological measurements of sub-adult fish sampled from 1994 to 2017 were determined from fish inhabiting in these different habitats. Also, oxygen consumption rates and osmoregulatory parameters (branchial Na^+ /K^+ -ATPase, NKA activity and gene expression of the α1 subunit and α1a and α1b NKA isoforms, gill ionocytes morphology) were measured from fish living in three contrasted habitats and after exposure to and different salinities. At all the studied locations, only the leirus morphotype was observed with also limited morphological variations. No short term effect of salinity could be detected on oxygen consumption from fresh, brackish, and saltwater fish. In these animals, gill NKA activity was salinity-dependent with also less NKA α1b in FW- than in SW-fish. Ionocytes in FW-fish gills were located along the lamellae and at their base, whereas these cells were restricted to gill filaments in SW-fish. Finally, electron microscopy revealed three different types of apical structures for these ionocytes: a honeycomb-like structure and a dome shape in FW, and deeply encrypted in SW. Therefore, sticklebacks of the Camargue area living in contrasted saline conditions belong to a very homogenous euryhaline population and are not exposed to strong metabolic demands due to salinity changes.

91-3 RIOS-SOTELO, G. R.*; NORTHUP, D.; BUECHER, D.; VOYLES, J. L.; Univ. of Nevada, Reno, Univ. of New Mexico; *gabriela18@gmail.com*

Skin Secretions May Provide Bats with Innate Immune Defenses Against Pseudogymnoascus destructans

White-nose Syndrome is an emerging infectious disease that has devastated bat populations in North America. The disease is caused by the lethal fungal pathogen *Pseudogymnoascus destructans* (commonly called "*Pd*"). Although there are different responses to infection among bat species, the underlying mechanisms that lead to interspecific susceptibility are unknown. In many mammals, the innate response is the "front line" of defense against infectious pathogens and can include a diversity of non-specific antimicrobial capabilities. In particular, mammals defend against cutaneous fungal pathogens with skin bacteria and chemical secretions that are released from epidermal glands at the skin surface. Some skin secretions contain antimicrobial peptides (AMPs), which may inhibit colonization and growth of infectious pathogens such as *Pd*. We hypothesized that different species may have a diversity of AMPs in their skin secretions that differentially inhibit *Pd* growth. To test this hypothesis, we collected skin swab samples of the wing surface from multiple bat species in several critical hibernacula of New Mexico to test their ability to inhibit *Pd* growth in in vitro challenge assays. We found that skin secretions from different bat species vary in their effectiveness at limiting *Pd* growth. These results suggest that we may be able to characterize skin secretions to determine which bat species could be more susceptible to White-nose syndrome prior to arrival of the pathogen. This information may help guide management and conservation management decisions for bats facing the threat of White-nose syndrome.

P2-78 RIPPAMONTI, JD*; DZIALOWSKI, EM; University of North Texas; *JessicaRippamonti@my.unt.edu*

The Role of Thyroid Hormone on Development of Endothermy in White Leghorn Chickens (Gallus gallus)

As chickens hatch, there is a rapid change in their physiology and metabolism associated with attaining endothermy. It is thought that thyroid hormones (TH) play a major role regulating the developmental changes at hatching. In birds, TH regulates skeletal muscle growth, which has a direct impact on the chick's ability to thermoregulate via shivering thermogenesis. To better understand the role of thyroid hormone (TH) in the timing of hatching, the development of thermogenic capacity, and metabolic rate, we manipulated plasma TH levels in chicken embryos beginning at 85% development (day 17 of a 21 day incubation) with either thyroperoxidase inhibitor methimazole (MMI) or supplemental triiodothyronine (T3). After TH manipulation, we characterized O_2 consumption and body temperature in the thermal neutral zone and during gradual cooling. Externally pipped embryos, newly hatched 0 day post-hatch (dph), and 1 dph chicks were cooled from 35 to 15°C. Measurements of blood plasma after TH manipulation confirmed both hyperthyroid and hypothyroid conditions. Manipulation of TH altered the timing of hatching, accelerating under hyperthyroid conditions and decelerating with hypothyroid conditions. At rest, there were no differences in resting metabolic rate and body temperature across TH treatment levels. Hyperthyroid EP animals were able to maintain metabolic rate over a wider range of ambient temperatures compared to control and hypothyroid animals. Here, we find that elevating TH levels prior to hatching accelerated hatching and the animal's thermogenic ability to respond to cooling.

P3-225 RITSCHARD, EA*; FITAK, RR; JOHNSEN, S; Los Andes University, Bogota, Colombia, Duke University, Durham, NC, USA; *ea.ritschard10@uniandes.edu.co*

Sensory insights from the molecular evolution of GPCRs in the Octopus bimaculoides genome

The evolution of cephalopod neural and morphological novelties has been attributed at a genomic level to independent gene family expansions. In the *Octopus bimaculoides* genome, one such expansion occurred in the G-protein coupled receptors (GPCRs) repertoire, a family of transmembrane proteins involved in a variety of functions in eukaryotes. In animals, one of the predominant functions of GPCRs is mediating signal transduction in various sensory systems. Here we assessed the relationship between this GPCRs repertoire expansion and the cephalopods' remarkable sensory abilities which make use of highly developed organs that resemble vertebrate sense organs in complexity. To study the evolutionary mechanisms that drove this expansion we first constructed a Bayesian phylogenetic tree using the *O. bimaculoides* GPCR repertoire. Diversification rates and positive selection (Ka/Ks) analyses suggested that three clades within the tree suffered an accelerated diversification process, two of them associated with positive selection. Functional predictions of the proteins of one of the positively selected clades, represented by rhodopsin-like GPCRs, indicated a possible role as somatostatin receptors. Somatostatin is a neurotransmitter concentrated in the optic lobe of cephalopods and localized to an area analogous to the vertebrate retina. Despite the need for further investigation, our result suggests an important role of GPCRs during the convergent evolution of the cephalopod and vertebrate visual systems.

59-4 RIVERA, HE*; TARRANT, AM; Woods Hole Oceanographic Institution; *hrivera@whoi.edu*

Contributions of parental effects vs. local adaptation to increasing thermal tolerance of larvae of the cnidarian model organism, Nematostella vectensis.

While organisms may adapt to local environments over many generations, those exposed to acute stress may confer stress tolerance to their progeny on shorter time scales through processes such as protective parental effects. In an era of rapidly changing environmental conditions, shorter-term mechanisms may be vital to the survival of many species, especially if such processes can provide protection comparable to that of longer-term adaptation. The anemone *Nematostella vectensis* is found in isolated estuaries from Canada to the southern United States. Their large latitudinal range and physically constrained habitats have facilitated genetic divergence between populations and adaptation to their local environments. We subjected *N. vectensis* from Massachusetts to acute heat stress and measured the thermal tolerance of their larvae. We find an increase in the temperature at which 50% of the larvae suffer mortality (LT50) in progeny from heat-stressed parents comparable to LT50 differences between Massachusetts and Maryland populations. Further experiments are in progress to compare the thermal tolerances of larvae from heat-stressed Massachusetts parents with those from South Carolina parents, as well as hybrid larvae resulting from crosses between the two populations. If protective parental effects can provide substantial thermal resistance to offspring, more rapid acclimatization to environmental stress may be able to occur. Understanding these processes can also elucidate of the fate of other cnidarians such as corals, which are highly susceptible to heat stress.

P2-131 RIVERA, HE*; COHEN, AL; BAUMS, IB; TARRANT, AM; THOMPSON, JR; DEVLIN-DURANTE, M; BARKLEY, HC; DRENKARD, E; MOLLICA, NR; YOUNG, C; Woods Hole Oceanographic Inst. (WHOI), WHOI, Pennsylvania State Univ. (PSU), Massachusetts Inst. of Technology, PSU, NOAA Southwest Fisheries Science Center, Scripps Inst. of Oceanography, Joint Inst. for Marine and Atmospheric Research Univ. of Hawaii - NOAA Pacific Islands Fisheries Science Center; *hrivera@whoi.edu*

Genetic connectivity of Porites lobata in the marine protected areas of the central Equatorial Pacific

The Phoenix Islands Protected Area (PIPA) and Jarvis, a protected US territory, in the central Equatorial Pacific host vibrant coral assemblages safeguarded from direct human impacts, yet remain vulnerable to heat stress. During 2014-16 El Niño, Jarvis experienced >90% coral mortality after a year of high temperatures. Connectivity between healthy and affected reefs can facilitate recovery; however, patterns of gene flow among coral populations in this region are still understudied. We quantified levels of gene flow for the major reef-building coral, *Porites lobata*, across PIPA and Jarvis using thirteen microsatellite markers. We find significant differentiation among reefs (global FST = 0.02, $p<0.0001$), with pairwise FST ranging from 0.007-0.09. Principal component analysis and Bayesian clustering methods find that the PIPA is subdivided into two subpopulations: the northeastern (NE) islands of Kanton, Birnie, Enderbury, and Rawaki and the southwestern (SW) islands of Orona, Manra, McKean, and Nikumaroro. During El Niño events, the NE islands can experience strong temperature anomalies and high levels of bleaching and mortality. Our results suggest the SW islands, which experience milder temperature stress and likely lower mortality, may have limited potential to re-populate the NE. The NE may therefore be dependent on self-seeding or dispersal through the equatorial current from reefs further east such as the Line Islands, El Niño events, however, often cause mortality in these reefs also. Region-wide monitoring of El Niño impacts combined with gene flow estimates will improve management of these diverse and remote reefs.

S3-9 RIVERA, AS*; ARENZ, AL; KOYAMA, KH; SAJUTHI, A; TSANG, S; CARRILLO-ZAZUETA, B; KIM, A; SASAKI, L; LIM, B; University of the Pacific; *arivera@pacific.edu*

Gene regulation, heterochrony, and predation: An eco/evo/devo perspective on eye loss in an ostracod crustacean.

The loss of a complex adaptive trait is typically associated with a move of a species to a new environment. This move results in changes in multiple traits, thus confounding genetic dissection of the loss. One way to address this is by examining sexually dimorphic species, here the ostracod crustacean *Euphilomedes carcharodonta*. Eye loss in *Euphilomedes* adults is restricted to females, who are largely benthic, compared to benthic/pelagic males. Comparisons between male and female eye development show that a handful of key regulatory genes are expressed at lower levels in developing female eyes. Moreover, both males and females exhibit heterochrony with regards to their eye development compared to other species of ostracods. This suggests that eye loss in this species requires two steps: 1) A heterochronic shift suppressing embryonic eye development, affecting both males and females 2) Redeployment of embryonic developmental regulators in male eyes to de-suppress eye development. This complex evolutionary history can be explained by dispersal mechanisms in males compared to females. Males appear to disperse, using their eyes in the water column to avoid predators, while females tend to be benthic and likely have much lower dispersal. We show that blindfolded males disperse and move towards females at similar rates to mock blindfolded males. This suggests that niche segregation, and not mate choice/acquisition, is driving the dimorphism.

P3-137 RIVERA-FIGUEROA, V*; LOUBRIEL, D; JOHNSON, M; TSCHEULIN, T; PETANIDOU, T; OSKAY, D; GONZALEZ, VH; HRANITZ, JM; BARTHELL, JF; AGOSTO-RIVERA, JL; University of Puerto Rico, Río Piedras, Dickinson College, Pennsylvania, University of the Aegean, Greece, Namik Kemal Üniversitesi, Turkey, University of Kansas, Bloomsburg University of Pennsylvania, University of Central Oklahoma, Edmond; *vilneryrivera@gmail.com*

Comparison of the Circadian Rhythms of Two Bee Pollinators, a Generalist and a Specialist, of Field Bindweed.

Circadian rhythm results from environmental factors and the intrinsic circadian clock of an organism. We studied two species of bees and common pollinators of the field (*Convolvulus arvensis*) flowers, *Lasioglossum malachurum* (generalist) and *Systropha curvicornis* (specialist) on Lesvos Island, Greece. *C. arvensis* produces flowers with an average life of less than 24 hours. Pollinators prefer to visit the flowers in early hours when rewards are most abundant. After observing these two species visit flowers, our goal was to compare the circadian rhythm of locomotor activity by these species. Bees were collected from two field sites and placed into an activity monitor to assay their circadian rhythms under controlled conditions in an environmental chamber. We tested the activity of both species inside the chamber under oscillating (simulated) field conditions and constant conditions by manipulating three factors; temperature, humidity and light. *L. malachurum* displayed high levels of activity throughout the 24-h period, with bimodal peaks in activity, consistent with our expectations for a generalist, social bee that forages and maintains a social nest. *S. curvicornis* displayed a discrete period of high activity slightly longer than the flowering time of *C. arvensis*. The circadian rhythm of *S. curvicornis* agrees with our expectations for a solitary specialist bee. Our comparison of these two bees reveals an interesting interplay among environmental conditions and bee life history that requires further study.

65-2 ROBART, AR*; WATTS, HE; Washington State University; *ashley.robart@wsu.edu*

Social Environment Influences Response to Declining Food Availability in a Facultative Migrant

Facultative migration is characterized by unpredictable, highly variable patterns of movement that vary in both direction and timing. Studies suggest a decline in food availability can trigger migration in an attempt to locate more favorable habitat. Many facultative migrants feed on conifer seeds, which vary both spatially and temporally in abundance. Since social information can increase foraging success in unpredictable habitats, facultative migrants may utilize information gained from conspecifics about local conditions when migrating in response to a reduction in food. Pine siskins (*Spinus pinus*) are a nomadic, irruptive migratory finch and exhibit behavioral and physiological responses to declining food availability that suggests a migratory transition. To examine the effect of social environment on response to food availability, birds received either *ad libitum* food (control) or a restricted diet and were housed such that they could either hear only birds experiencing the same food treatment as themselves or hear birds from both food treatments. Birds in the all-food restricted group had significantly higher daytime activity levels compared to birds in the all-control group. Both control and food restricted birds in the mixed-treatment group had activity levels that were intermediate between the all-control and all-food restricted groups. Birds in the all-food restricted group gained more weight post-restriction compared to food restricted birds in the mixed-treatment group. Unexpectedly, circulating corticosterone levels increased in all groups during food restriction. These results suggest pine siskins integrate vocally-communicated information gained from other group members when responding to declining resources, which may have population-level effects across a dynamic environmental landscape.

P2-62 ROBBINS, K*; MASLAKOVA, SA; VON DASSOW, G; Oregon Institute of Marine Biology, University of Oregon; *krobbin3@uoregon.edu*

A microsporidian infests oocytes of the ribbon worm Maculaura alaskensis

We describe a microsporidian parasite that we recently discovered within the oocytes of wild-caught *Maculaura alaskensis* in Coos Bay, Oregon. *M. alaskensis* is a pilidiophoran heteronemertean common to sandy mudflats of Washington and Oregon, which has been the basis for several previous developmental studies; microsporidians are closely related to fungi and live as obligate intracellular parasites of animals and protists. We find the parasite in both dissected oocytes and spontaneous laboratory spawnings of *M. alaskensis*, most commonly near the end of their normal reproductive season. Some fraction of oocytes released from infected females contain one to several parasitophorous vesicles, visible by transmitted light microscopy, containing dozens to hundreds of apparent spores. Each mature spore contains two nuclei and a polar tube, traits distinctive for microsporidia. Some infected oocytes develop a chorion-like investment, a feature not typically observed in healthy oocytes of *M. alaskensis*. In the laboratory, spore-bearing oocytes can be fertilized with varying success, and occasionally yield overtly-infected pilidium larvae. Our present goals are to develop methods to allow us to determine which microsporidian life stages are present in oocytes, larvae, and adult tissues, and thereby characterize the parasite's life cycle, discover its mode of transmission, and assess its influence on host reproduction and development.

11-6 ROBERTS, NS*; MENDELSON, TC; Univ. of Maryland, Baltimore County; *nat17@umbc.edu*

A potential role for reinforcement in the evolution of female preferences in the banded darter (Etheostoma zonale)

Behavioral isolation typically evolves as a by-product of divergence in mating preferences between geographically isolated populations, but it also can be strengthened upon secondary contact by reinforcement. Reinforcement occurs when hybrid offspring have reduced fitness, leading to stronger prezygotic isolation in sympatry than in allopatry. Behavioral isolation appears to be important in the speciation process for darter fishes (Percidae: *Etheostoma*); however, some allopatric pairs of darter species lack preference for conspecifics, sometimes even preferring heterospecific phenotypes, suggesting that divergence in geographic isolation alone may be insufficient to maintain species boundaries. Therefore, we tested the hypothesis that reinforcement strengthens behavioral isolation between the partially sympatric darter species *Etheostoma zonale* and *E. barrenense*. Previous work has found that both sexes of *E. zonale* significantly prefer conspecifics over sympatric *E. barrenense*. In the current study, we collected *E. zonale* from populations allopatric with respect to *E. barrenense* and measured male and female preferences for con- and heterospecific stimuli, predicting that strength of preference would be greater in sympatry than in allopatry. We used a general linear model to test the effect of sex and sympatry on strength of conspecific preference. Results show that the interaction of sex and sympatry significantly predicts strength of preference in *E. zonale*; specifically, female strength of preference decreases with increased distance from sympatry, whereas male preferences were similar across all populations. Our results therefore suggest that reinforcement is shaping female preferences and that male preferences may be evolving earlier than females' in allopatry.

79-7 ROBERTS, B.*; BOGAN, J.; HOFFMAN, M.; TERRELL, K.; Dept. Research and Conservation, Memphis Zoo, Central Florida Zoo, Orianne Center for Indigo Conservation, Central Florida Zoo; *broberts@memphiszoo.org*

Lack of Complement Protein Defense Against Both Primary and Opportunistic Pathogens in Eastern Indigo Snakes (Drymarchon couperi)

Infectious diseases are a significant threat to the conservation of wildlife, but little is known about host-pathogen relationships in reptiles. The eastern indigo snake (*Drymarchon couperi*) is federally endangered due to the loss and degradation of its habitat in the U.S. Southeastern Coastal Plain. Wild populations are seasonally susceptible to ulcerative skin lesions, and these wounds provide increased opportunity for internal infections. Thus, there is a need to better understand the mechanisms of disease resistance in this species. Our study investigated plasma complement-based immunity of eastern indigo snakes against five bacterial species. We tested the hypothesis that snake complement proteins are less effective at killing the relatively virulent bacterium, *Staphylococcus aureus*, compared to opportunistic pathogens commonly isolated from reptiles. Plasma was collected from captive adult snakes (n = 9) and frozen at -80°C until analysis using an absorbance-based assay. We found that snake plasma killed high proportions of *Escherichia coli* (63.8% ± 3.8; CV=18%) and *Pseudomonas aeruginosa* (51.0 ± 7.1%, CV=42%). However, killing ability was lower and more variable against *S. aureus* (12.4 ± 5.0%, CV =90%), *Salmonella arizonae* (15.1 ± 5.8%, CV=95%) and *Klebsiella oxytoca* (2.0 ± 2.8%, CV=84%). Our findings suggest that eastern indigo snakes may be relatively more susceptible to infection with *Salmonella* and *Klesbiella* compared to other opportunistic pathogens. Further study is needed to understand how these differences in plasma killing ability influence morbidity and mortality in eastern indigo snakes.

109-8 ROBERTS, EA*; CARRINGTON, E; Univ. of Washington; *earobert@uw.edu*

Incorporating structural biomaterials into a bioenergetics framework: an empirical test with marine mussels

A key challenge for ecological physiologists is to determine how long and short-term environmental variation will influence organisms in current and future climate scenarios. Bioenergetic models, such as Scope for Growth (SFG), are used to integrate variation in food availability and temperature into changes in organismal biomass. These frameworks do not explicitly consider the costs of structural biomaterials, such as those that play a role in attachment, mechanical defense and other traits critical to an organism's survival. We hypothesized the production of biomaterials may be influenced by the energetic state of the organism. We developed several SFG models using alternative ‘allocation rules' that describe how energy might be prioritized among maintenance, growth, and biomaterials in congener marine mussels, *Mytilus trossulus* and *Mytilus galloprovincialis*. Mussels produce structural biomaterials called byssal threads to anchor themselves to rocky shores. Byssal thread attachment strength varies annually and is influenced by abiotic conditions. We ask, does byssal thread production depend on mussel energetics? We perturbed mussel energetic state by manipulating food availability and temperature in a mesocosm experiment. We evaluated five alternative models (each with different allocation rules) for their ability to predict the relationship between thread production and tissue growth using Akaike Information Criteria (AIC). Two models were well supported by the data: thread production is proportional to 1) all energy available, or 2) maintenance. This study establishes relationships between soft-tissue and structural material fluxes in mussels, and serves as a model system for incorporating structural materials into bioenergetics models.

28-2 ROBERTS, KT*; RANK, NE; DAHLHOFF, EP; STILLMAN, JH; WILLIAMS, CM; Univ. of California, Berkeley, Sonoma State Univ., Santa Clara Univ.; *kevrob@berkeley.edu*

Carryover effects of cold on overwintering willow leaf beetles

In insects, cold hardiness is plastic, and can be induced seasonally and in response to acute cold exposure. Acute cold exposure can also cause cellular damage, which can decrease survival of a subsequent cold exposure. Thus, a cold snap can have physiological carryover effects that impact responses to subsequent cold. These carryover effects depend on the severity of cold stress experienced. We aimed to test for carryover effects of cold exposure in overwintering adult willow leaf beetles (*Chrysomela aeneicollis*). We manipulated duration, intensity, and number of cold exposure, and recorded survival of a subsequent cold stress. We measured cryoprotectant levels, which prevent cold injury and are accumulated seasonally and in response to cold exposure. Relatively mild cold exposures did not influence survival to a subsequent cold stress, but a more intense cold exposure reduced survival. High cryoprotectant abundance was positively related to survival after a subsequent cold exposure, regardless of type of cold exposure. There was no difference in cryoprotectant accumulation between treatments indicating that rapid cryoprotectant synthesis may be limited in these beetles at low overwintering temperatures. This data suggest that carryover effects will not occur in response to mild cold exposures, but that severe cold could cause damage that reduces resistance to subsequent cold snaps.

P1-191 ROBINSON, CD*; GIFFORD, ME; University of Central Arkansas; *crobinson19@cub.uca.edu*

Thermally-induced signal plasticity does not reflect individual performance variation across temperatures in prairie lizards

Physiological changes in response to environmental cues are not uncommon. Temperature has a strong effect on many traits, such that traits follow stereotyped thermal performance curves in response to increasing temperature. The prairie lizard, an abundant ectotherm throughout the central United States, has thermally sensitive, blue abdominal and throat patches. Currently, the role of these patches is not well understood. In this study, we set out to investigate whether individual plasticity in patch color mimicked individual plasticity in sprint speed (do they covary?) and if the plasticity in these two patches signal redundant or complementary information, testing competing hypotheses suggested for the evolution of multiple signals. We found that although patch hue exhibited stereotyped thermal performance curves, thermal plasticity in patch color did not mimic thermal plasticity in performance at the individual level. But we did find strong support for the hypothesis suggesting that these two patches signal redundant information through covariation of color across temperatures. The importance of better understanding the function of individual variation cannot be overstated and, overall, more work is needed to better understand the ultimate mechanisms underlying signal plasticity in this species and others.

119-1 ROBINSON, CD*; GIFFORD, ME; University of Central Arkansas; *crobinson19@cub.uca.edu*

Selection on a sexually dimorphic color patch in the prairie lizard, Sceloporus consobrinus

Color can serve many functions, including aiding in thermoregulation, advertising performance ability, and attracting mates. In the prairie lizard (*Sceloporus consobrinus*), males have large, blue abdominal and throat patches that develop in response to increasing testosterone levels at sexual maturity. Beyond being used as a sex recognition tool, not much is known about the significance of these patches. Our previous work has demonstrated that individuals with intermediate testosterone levels had the brightest patches and that those with larger throat patches have greater endurance. Because both testosterone and endurance can affect individual fitness, we were interested in understanding how selection acted on patch morphology (color, size) in the prairie lizard. In this study, we conducted a multi-year mark recapture study using a population of *S. consobrinus* in central Arkansas. For two consecutive breeding seasons, we quantified patch morphology, testosterone levels, endurance, home range, and fitness for each male in the population. Using logistic regression analyses, we estimated linear (directional) and quadratic (stabilizing/disruptive) selection gradients to understand how fitness was related to patch morphology. We then followed these analyses up with path analysis to understand how individual testosterone levels mediate the relationship between fitness and patch morphology.

64-2 ROCK, AQ*; STEPHENSON, TB; DUBUC, TQ; MARTINDALE, MQ; Whitney Laboratory for Marine Bioscience, University of Florida, Centre for Chromosomal Biology, National University of Ireland Galway; *arock@bowdoin.edu*

The maternally expressed Hox gene Ax6a is required for gastrulation and the formation of bilateral symmetry in the cnidarian Nematostella vectensis.

Hox genes are Homeobox transcription factors that are responsible for patterning along the primary axis and are found in all bilaterians, a group that makes up 99% of metazoan life. Cnidarians, such as anemones and corals, represent the only phylum outside of the Bilateria to have Hox genes, making them an important sister group for studying Hox gene evolution. The anthozoan gene Ax6a is a cnidarian specific Hox gene that has maternal expression and is expressed at the site of gastrulation, suggesting it has an important role in early development. Furthermore, Ax6a is asymmetrically expressed along the future site of gastrulation when visualized with *in situ* hybridization. When Ax6a is prevented from being expressed through the injection of eggs with an Ax6a antisense Morpholino, treated embryos fail to gastrulate and oral, aboral, and directive axis patterning is disrupted, suggesting that it has a large effect on the embryo's development outside of its own asymmetrical oral domain. Furthermore, when Ax6a mRNA is injected ectopically into random blastomeres at the 8-32 cell stage, a second site of invagination, and later, gastrulation is induced, with expression of some markers for oral development. This implies that Ax6a plays a very important role in axial patterning and suggests that anterior Hox genes may have had fundamental roles in establishing the primary body axis in the bilateral lineage.

50-2 ROCKMAN, MV*; ZAKAS, C; New York University; *mrockman@nyu.edu*

The Genetic Basis for Larval Life-History Dimorphism in the Polychaete Streblospio benedicti

Among benthic marine invertebrates, some species make small eggs that develop into complex planktotrophic larvae, while others make large eggs that develop into lecithotrophic larvae able to metamorphose into benthic juveniles without ever feeding. Transitions between these two resource-allocation strategies are common in evolutionary history. *Streblospio benedicti* is one of a handful of species in which both strategies occur. Developmental mode is highly heritable in *S. benedicti*, and we have used experimental crosses to dissect the genetic basis for differences between planktotrophs and lecithotrophs. By genetically mapping different aspects of larval development to the *S. benedicti* genome, we have discovered that, larval size, which is governed by maternal genetic effects, varies due to loci unlinked to loci that act zygotically to shape larval morphology. This genetic architecture of larval development — joint determination by unlinked maternal- and zygotic-effect loci — shapes the possibilities for phenotypic evolution. Zygotic effect alleles find themselves in maternal-effect backgrounds according to the local maternal-effect allele frequencies, creating positive frequency-dependent selection. In other words, egg-size allele frequencies are the selective environment for larval morphology alleles.

S4-6 RODENBECK, EW; Stamen Design; *erode@stamen.com*
Inviting inquiry and exploration through data visualization
Science, in the popular imagination, is about finding answers to questions. Scientists make discoveries, develop theories, and deliver those discoveries and theories to neutral audiences with an interest in the truth as backed up by science. Well-designed data visualization (dataviz), by contrast, can invite more questions than it answers. It has the particular quality of allowing its viewers, users and makers the ability to generate new kinds of questions, and to put them in a better place to answer those questions. By the creation of objects to think with, dataviz opens up landscapes of possibility for discussion and inquiry that can help scientists to both do their work and better communicate their work to broader audiences. The focus of dataviz can be understood to exist along a spectrum of abstraction, from facts at the most concrete end, to wisdom, knowledge, and even vision as the most aspirational place for dataviz to work. Each of these kinds of work requires a different approach. Through our client-facing and research practice at Stamen, we engage in multiple kinds of dataviz approaches across this spectrum. Much of this work is done for and with scientists across a broad range of fields, from metagenomics to an atlas of human emotions. This talk will illustrate and examine examples from multiple points along the rich and varied possibility space that opens up when science and dataviz work together. When it comes to communication and visual interfaces, what you lose in detail, you can gain in power. This can be a difficult notion for the scientific mind to navigate. Well-designed dataviz can help find ways for scientists to navigate the multiple competing interests and priorities inherent in both communication to non-scientists and exploratory data-rich interfaces.

P1-257 RODERICK, WRT*; CHIN, DD; CUTKOSKY, MR; LENTINK, D; Stanford University; *wrtr@stanford.edu*
How birds get a grip: Characterizing claw-surface interactions in perching birds
Everyday, birds land and take off from branches that vary widely in size and texture. Yet, despite our familiarity with these behaviors, we do not fully understand how birds integrate the use of aerodynamic braking, energy absorption from the legs, and friction at their feet to land and take off so reliably. In this work, we examine how the feet of birds facilitate attachment on irregular surfaces. We measured the claws from four Pacific parrotlets and developed a model to describe claw shape. We also experimentally determined the friction forces between the contact surfaces of a bird's foot and a variety of natural and human-made surfaces. With this data, we can answer key questions about how birds manipulate friction on a wide range of surfaces and the mechanisms in their feet that enable this versatility. We compare these results to the friction of the claws and spines used in perching aerial robots for insight into aerial robot design.

128-5 RODRIGUEZ, J; VELAZCO, L; HADDAD, R; MONTGOMERY, J; LAURI, M; MONTELONGO, M; ROSS, J*; CSU Fresno; *jross@csufresno.edu*
Mitochondrial dysfunction influences development and nuclear allele segregation in intra-species hybrids
Intra-species hybridization can result in mitochondrial dysfunction due to recombination of epistatic mitochondrial-nuclear alleles that coevolved to maintain electron transport chain (ETC) function within each population. However, mitochondria also play many roles, such as apoptosis, in cellular functions not directly related to ATP production. Thus, outstanding questions include whether hybrid dysfunction phenotypes are related to ETC dysfunction, and what are the identities of the genetic variants that induce hybrid mitochondrial dysfunction. Cytoplasmic-nuclear hybrids (cybrids) of the nematode *Caenorhabditis briggsae* suffer from mitochondrial dysfunction. A fraction of F2 hybrids also experience a 25% delay in development rate compared to wild-type siblings. We inquired whether mitochondrial dysfunction underlies developmental delay. We analyzed developmental timing in *C. briggsae*, comparing parental, F2, and cybrid strains. F2 hybrids and cybrids exhibited developmental delay. F2 delayed hybrids differ in mitochondrial biochemistry from their wild-type F2 siblings. Genetic mapping using F2 hybrids, near-isogenic and advanced-intercross recombinant inbred lines identified a nuclear locus related to hybrid incompatibility. We also produced and genotyped cybrids at two temperatures and found temperature-dependent complex allele segregation patterns. This segregation distortion suggests both an interaction between environment and genotype on hybrid fitness and also that multiple nuclear alleles are involved in mitochondrial coevolution. A key implication of these results is establishing a connection between genotype, cellular biochemistry, an organismal phenotype, and individual fitness.

P1-251 RODRIGUEZ, AM*; TAFF, CC; ZIMMER, C; VITOUSEK, MN; Cornell University; *amr394@cornell.edu*
Don't Get Your Feathers Ruffled: Exploring Candidate Mechanisms Linking Plumage Color and Stress Resilience in Tree Swallows
Signal traits can convey information about an individual's physiological state. These signals often serve an important role in social interactions - including mate choice - and thus can impact fitness. In tree swallows (*Tachycineta bicolor*), individuals with brighter feathers are more socially connected and more resilient under stress (Taff et. al. in prep). Little is known about the mechanisms that underlie this pattern, or the relationship between plumage color and physiological state in tree swallows. Here, we test the relationships between ventral feather brightness and several physiological measures: circulating corticosterone, oxidative stress, and blood glucose levels. Because brighter tree swallows are more stress resilient, we predict that incubating females with brighter ventral feathers will have lower levels of both baseline and stress-induced corticosterone, exhibit stronger negative feedback in the hypothalamic-pituitary-adrenal axis, and suffer from less oxidative damage. Uncovering plumage-physiology links may provide insight into candidate mechanisms linking signal traits with social interactions, performance, and fitness.

105-3 ROEGNER, ME*; CHEN, HY; WATSON, RD; ROEGNER, Megan; University of Alabama at Birmingham; *mzappe@uab.edu*
Regulation of intracellular Ca^{2+} signaling in molting glands of the blue crab, Callinectes sapidus.
In crustaceans, cycles of growth and molting are triggered by cholesterol-derived molting hormones (ecdysteroids) released from paired endocrine glands (the Y-organs) located in the anterior cephalothorax. During much of the molting cycle, the levels of ecdysteroids in hemolymph are kept low by the action of a peptide molt-inhibiting hormone (MIH), produced in the eyestalks. While the removal of MIH suppression during pre-molt coincides with increased ecdysteroidogenesis, there is evidence that an additional positive stimulus in the form of an intracellular Ca^{2+} signal also plays a significant role. To better understand Ca^{2+} signaling in Y-organs, our lab investigated the proteins involved in regulation of intracellular Ca^{2+}. These include Ca^{2+} pumps, e.g., plasma membrane calcium ATPases (PMCAs) and sarco/endoplasmic reticulum calcium ATPases (SERCAs). We used a PCR-based cloning strategy (RT-PCR followed by 3′- and 5′-RACE) to clone a full-length cDNA encoding a putative SERCA protein from the Y-organs of the blue crab (*Callinectes sapidus*). SERCA transcript levels in Y-organs were then determined using quantitative PCR. Transcript abundance was assessed after Y-organs were activated by eyestalk ablation, and throughout a natural molting cycle. The results are consistent with the hypothesis that stage-specific changes in SERCA expression occur in response to increased intracellular Ca^{2+} and are not a causative factor in promoting ecdysteroidogenesis. Identification of the stimulus that drives the increase in intracellular Ca^{2+} is critical to an understanding of cellular mechanisms that regulate ecdysteroidogenesis in crustacean molting glands.

100-4 ROGERS, EJ*; SOMMERS, AS; MCGUIRE, LP; Texas Tech University; *elizabeth.j.rogers@ttu.edu*
Summer Variation in Fat Storage and Lipid Oxidative Capacity in the Brazilian Free-tailed Bat
As small-bodied, flying mammals, insectivorous bats experience substantial, but variable, energetic demands. In the summer, females experience the greatest demands during reproduction, particularly due to increases in wing loading and long periods of lactation. Following lactation, there is a period of comparatively lower energy demand prior to fall migration. To compensate for periods of greater energy demand, we hypothesized that bats increase fat storage and lipid oxidative capacity. Using quantitative magnetic resonance, we measured fat mass in a maternity colony of Brazilian free-tailed bats (*Tadarida brasiliensis*) over the course of the summer active season. We also collected pectoral muscle at multiple time points spanning the reproductive cycle and measured changes in the activity of three catabolic enzymes that are known to be upregulated in bats during migration. We found that fat mass decreased from mid-pregnancy through lactation, suggesting that females rely, at least partially, on stored fat to fuel reproductive events. Males, which don't experience reproductive costs in the summer, showed little variation in fat mass. Analysis of catabolic enzyme activity in flight muscle is ongoing, and will reveal whether parallel variation in lipid oxidative capacity occurs with the observed variation in fat stores. Unlike running mammals, bats rely on extramuscular fat stores to fuel high intensity exercise, and this research will determine whether bats require additional physiological compensation to continue powering flight during energetically demanding life-cycle stages. More broadly, the present study addresses the ability of animals to maintain energy balance by adjusting flexible physiological and biochemical traits in response to periodic changes in energy demand.

92-6 ROGERS, D.C.; University of Kansas; *Branchiopod@gmail.com*
Anostracan mate searching behaviour
Anostracans have some of the most elaborate mating behaviour among crustaceans. Specific mating rituals have been studied in detail elsewhere. I examined the behaviours of several anostracan species as they were specifically seeking potential mates. Males and females were reared from egg onward in isolation. Males demonstrated specific seeking behaviours, cruising in the lower water column around salient objects. Receptive females hovered around salient objects high in the water column, allowing males to approach from beneath. Unreceptive females and males never exposed to females tended to stay low in the water column and moved around little. However, these same isolated males immediately began searching behaviours when water from female cultures was added, demonstrating that sex pheromones are involved. Finally, the first record of anostracan male: male aggressive interaction is presented.

125-5 ROHNER, N; Stowers Institute for Medical Research; *nro@stowers.org*
Cavefish Metabolic Adaptation: Hungry, Fat, and Healthy
Understanding the genetic basis of adaptation has broad implications not only for a basic understanding of evolution, but also for human pathologies given that many human diseases are a consequence of mis-adaptation to modern societies. The emerging model system Astyanax mexicanus has become an important fish species to address adaptation to extreme environments due to its unique ecology and the availability of genetic tools and genomic resources. Cave environments are typically dark and as a consequence nutrient deprived. We have previously shown that cavefish acquired impressive adaptations such as hyperphagia (increased appetite), starvation resistance and altered feeding behaviors to cope with these conditions. In this study we have found cavefish to display elevated blood sugar levels and strong insulin resistance compared to surface fish, but without any effect on the health of the fish. On the contrary, we show that these phenotypes are helping the cavefish to gain weight more quickly as part of their starvation resistance strategy. Using whole genome information of different cave and surface populations, we identified mutations in the insulin receptor of cavefish underlying the observed insulin resistant phenotypes. We use CRISPR mediated gene editing to show that this mutation is sufficient to cause a similar phenotype in zebrafish and provide evidence for strong selection of this allele in the wild. Interestingly, the same mutation is found in cases of Type 2 diabetic patients in human populations, raising the question whether cavefish can be used to gain insight into human glucose control homeostasis.

108-2 RONALD, KL*; HURLEY, LM; Indiana University; *kelly.lennington@gmail.com*
Female Signaling: Non-Redundant Multimodal Cues in the House Mouse Mus musculus
Multimodal signaling is nearly ubiquitous across animal taxa. Multimodal signal components are often classified based on whether they contain the same, or redundant information to the receiver (e.g., the backup hypothesis) or different, non-redundant information to the receiver (e.g., the multiple messages hypothesis). While much research has focused on male signal production contributing to female mate-choice or preferences, females often give their own multimodal cues during intersexual communication events. Here we investigated the role of two different female vocalizations produced by the female house mouse *Mus musculus*: the broadband, relatively low frequency squeak, and the higher frequency, frequency modulated ultrasonic vocalizations (USVs). We then presented these vocalizations with and without female urine in a cue-isolation experiment to male receivers. This would allow to establish whether female multimodal cues followed the predictions of the backup or multiple messages hypothesis. We found that female urine and vocalizations act as non-redundant multimodal cues as males responded with different behaviors and vocalization patterns depending on the social context. Specifically, male investigative behavior was greatest when urine was present. Similarly, males made more USVs (both with and without harmonics) when urine was present. In contrast, the addition of urine to squeaks and USVs did not alter male vocal behaviors relative to urine alone. Our data suggest that female urine, rather than female vocalizations, influences male vocal courtship in this experimental paradigm. Furthermore, these results suggest that intersexual interactions between mice are highly complex and are dependent on feedback from both social partners, males and females alike.

P3-197 ROOP, SR*; PRUETT, J; SAATHOFF, MM; ADDIS, EA; Gonzaga University, Auburn University; *sroop@zagmail.gonzaga.edu*
Maternal Nest-Site Selection and Hatching Success in a Northern Population of Painted Turtles (Chrysemys picta)
For most ectotherms, environmental temperature plays a pivotal role in their survival, as they are dependent on external sources for body heat, by definition. However, within many species, how temperature affects survival varies in different life history stages. For example, in painted turtles (*Chrysemys picta*) adults alternate between being in and out of the water, while newly hatched turtles spend much of their first year underground. Much of what we know about how ecological conditions associated with maternal-nest selection affect hatching success and overwinter survival in painted turtles come from studies in the Midwest. As *C. picta* is found over much of North America, this study explores how the ecological conditions affect hatching success in a population of *C. picta* near the northern edge of its range. Specifically, this study first examines the frequencies of canopy cover, soil moisture, and vegetation density of maternal nest-site selection and those variables' effects on temperatures within the nests throughout incubation. Second, this study focuses on the effects of both nest-site selection factors and temperature on hatching success. The results of maternal preferences for nest sites with low vegetation density percent, median canopy cover percent, and low soil moisture level will be correlated with temperatures within each nest through the incubation processes and hatching success. Future studies will examine the effects of these variables on over winter survival of the hatchlings.

P3-53 ROOT, LT*; CON, P; CNAANI, A; KüLTZ, D; Univ. of California, Davis, Inst. of Animal Sciences, Agricultural Research Org., Israel; *ltroot@ucdavis.edu*
Comparative intestinal proteome response to salinity stress in three tilapiine spp.
The relationship between animal growth and stress tolerance ability is complex, with evidence indicating antagonistic regulation of cellular processes which promote either high growth or tolerance. For example, breeding for improved growth rates in the tilapia species Oreochromis niloticus has inadvertently resulted in decreased tolerance to hypersaline water conditions. To examine changes in growth and stress tolerance at the cellular and tissue levels, high salinity acclimation challenges were conducted for three cichlid species, including the previously mentioned O. niloticus with reduced salinity tolerance, wild-type (WT) O. mossambicus which exhibit tolerance to salt concentrations greater than seawater, and WT Astatotilapia burtoni which exhibit low salinity tolerance. Three intestinal sections were sampled from salinity-challenged fish and from control fish maintained in freshwater, and used to establish a standardized data-independent acquisition (DIA) assay for label-free quantitative proteomics for a large number of proteins in each species. Spectral libraries created by data-dependent acquisition (DDA) and annotated using multiple search engines were used for DIA assay construction. Skyline and a sample training set were used for automated and manual assay curation to select and validate reproducible transitions and proteotypic peptides for protein quantitation. Salinity effects on intestinal protein expression patterns in each species were statistically evaluated and corresponding protein sets analyzed for gene ontology enrichment. The resulting data on salinity-dependent intestinal proteome dynamics provide insight into biochemical processes controlling growth and stress tolerance.

118-5 ROSARIO, MV*; ROBERTS, TJ; Brown University; *michael_rosario@brown.edu*
The ability of tendons to buffer energy during eccentric contractions depends on lengthening dynamics
When muscle-tendon units (MTU) absorb energy via active lengthening, energy flows into an elastic tendon before being dissipated by the muscle. Energy flow into the tendon has been hypothesized to act as a mechanical buffer, thereby reducing peak muscle force, velocity, and power input to the muscle. To fully test these hypotheses, however, experiments that completely limit the flow of energy into the tendon must be conducted. We performed these experiments *in silico* by creating a muscle-tendon simulation using parameters from turkey gastrocnemius muscles. The model was validated with experimental data, and tendon stiffness was adjusted such that our model matched previous experimental results. We virtually stretched active muscle-tendon units at different rates and measured muscle force, velocity, and power over time. We then modified the model to prevent energy flow into the tendon and repeated the simulation experiments. By comparing these two datasets, we found that tendons have a large capacity to reduce peak muscle velocity and power input (in some cases, completely eliminating muscle lengthening during the period of force rise). Reductions in peak muscle force were possible but were sensitive to the duration of lengthening. These results indicate that the ability of turkey tendons to buffer muscle force, velocity, and power are dependent on the interaction of lengthening and muscle dynamics.

P2-178 ROSE, CS*; ALEAGHA, O; MODOLO, C; HOGUET, N; James Madison Univ.; *rosecs@jmu.edu*
Xenopus tails are unique in combining whip-like lateral undulations and vertical extension and flexion
Unlike most tadpoles, *Xenopus* tadpoles feed by hovering mid water and pumping water through the branchial basket to filter food particles out of suspension. This requires lung-breathing to generate positive buoyancy throughout the larval period and tail beating to offset this buoyancy while feeding. In studying the ontogeny of both traits, we observed that *Xenopus* tails become increasingly whip-like in shape and behavior, meaning that they become tapered vertically, and their lateral undulations increase in both amplitude and wavelength as they travel to the tip. Measurements of fixed specimens indicated that tails usually become curved dorsally, though they can also curve ventrally or remain straight. Observations of living specimens confirmed that tail curvature is largely behavioral, rather than developmental, and that mature tadpoles appear to curve their tails dorsally when feeding to generate a weak but steady propulsive force that is directed more downward and less forward. Straight and ventrally curved tails are usually observed when the body is aligned horizontally at the top or bottom of the water column. Whip-like tails are rare in vertebrates, and are used for defense in lizards and hunting in thresher sharks. Vertical tail movement is also rare in in anamniotes, occurring in syngnathid fish and plethodontid salamanders with prehensile tails. We propose that *Xenopus* acquired this unique combination of developmental and behavioral traits to support feeding and defense as the whip-like tail is expected to focus predators' attention on the posterior extremity of the body, and is easily regenerated.

8-7 ROSENTAL, B*; KOWARSKY, M A; COREY, D N; ISHIZUKA, K J; PALMERI, K J; CHEN, S Y; SINHA, R; SEITA, J; QUAKE, S; WEISSMAN, I L; VOSKOBOYNIK, A; Stanford University School of Medicine. ; *benyamin@stanford.edu*
Evolutionary origin of the mammalian Hematopoietic and Immune systems found in a Colonial Chordate
To gain insight into the evolutionary relationship between vertebrate and invertebrate hematopoietic system, we have characterized the immune system and cell populations of the colonial tunicate Botryllus schlosseri. B. schlosseri belongs to a group considered the closest living invertebrate relative of vertebrates, it has bidirectional blood cell flow through an interconnected vasculature. To isolate and characterize the Botryllus cell populations we adapted Fluorescence-Activated Cell Sorting (FACS). We used Cytof Mass Cytometry to scan 50 diverse antibodies. Antibodies that differentially bind to B. schlosseri cells, in combination with lectins and fluorescent reagents activated by enzymes, were used to isolate live B. schlosseri cell types. Additionally, we used mouse serum against the Botryllus Histocompatibility Factor and analysis of cell size, granularity and auto fluorescence to isolate 34 cell populations. We prepared libraries from these populations for RNAseq, and analyzed their gene expression. This analysis revealed cell population homolog to mammalian hematopoietic stem cells, which upon transplantation, migrated to stem cell niche and differentiated into other cell lineages. Interestingly, we have shown that this niche is homolog to mammalian bone marrow stromal cells. Using functional immunological assays for cytotoxicity and phagocytosis we characterized 3 different phagocytic cell-types. One of these demonstrated transcriptional and functional features resembling myeloid cells in vertebrates. Furthermore, we identified a B. schlosseri cytotoxic cell population originating from large granular lymphocyte-like cells. Our data suggests that the common ancestor of tunicates and vertebrates had a true hematopoietic myeloid lineage, while the cytotoxic cells may result from a convergent evolutionary mechanism.

126-2 ROSENTHAL, MF*; KESSLER, B; MEZA, P; ELIAS, DO; University of California, Berkeley; *malcolm.rosenthal@berkeley.edu*
Examining Microhabitat Structure and its Use by Wolf Spiders
Ecological theory predicts that species will partition their habitat use to limit competition. For terrestrial invertebrates, it is possible that this partitioning will occur at extremely fine scales. Wolf spiders (Lycosidae) are often found in high densities, with multiple species present in overlapping habitats. In this study, we aim to (i) assess the fine-scale complexity of the wolf spider's habitat, (ii) determine to what degree spiders partition their use of the habitat by substrate type, and (iii) test the role of vibratory communication in substrate partitioning. We conducted a survey of wolf spider species noting the substrate on which each individual was caught, and mapped the locations and overlap of substrates over nine $10m^2$ plots. In the lab, we ran the two most abundant species, *Schizocosa floridana* and *Rabidosa hentzi*, in mating trials on the three most abundant substrates (oak, pine, & sand) to test whether mating success varied as a result of substrate type. We found that substrate microhabitat was highly complex, with over ten distinct substrates recorded, and most $10m^2$ plots containing three or more substrate types. 95% of *S. floridana* individuals were caught on oak or other deciduous litter, whereas 50% of *R. hentzi* individuals were caught on pine litter, suggesting a significant degree of substrate partitioning. In the lab, however, substrate did not significantly affect mating success in either species, suggesting that these patterns of habitat use are not the result of variation in vibratory communication efficacy.

P2-40 ROSERO, M*; FUSE, M; San Francisco State University; *mrosero@mail.sfsu.edu*
Assessing changes in the Juvenile Hormone downstream signal, Kruppel Homolog 1, after damage-induced developmental delays in the tobacco hornworm, Manduca sexta.
Holometabolous insects have been able to radiate and capture numerous ecological niches due to the appearance of unique appendages in the adults compared to the larvae. All appendages, such as the wings, and antennae, begin as clusters of undifferentiated cells called imaginal discs that propagate at the last larval instar. Inability to repair damage to imaginal discs could compromise body scaling; hence impairing their ability to radiate to required geographical niches. Delaying development has risen as a mechanism to combat this issue by giving damaged tissues enough time to regenerate. Damage to the imaginal discs of the hornworm, Manduca sexta, using X-ray radiation, results in delays to pupation and metamorphosis. It remains unclear how damaged imaginal discs signal the rest of the body to delay development, allowing them to recuperate from the damage. Interestingly, damaged larvae show increased critical weight, which suggests extended synthesis or slow degradation of the developmental hormone, Juvenile Hormone (JH), plays a role. Therefore, I hypothesized that damaged imaginal discs coordinate developmental delays through the actions of JH; thus, the decrease of JH downstream transcription factor kruppel homolog 1 (kr-h1) would be delayed in larvae damaged by x-ray radiation. I verified this by measuring changes kr-h1 using qRT-PCR. This study can be confirmed using JH agonists and antagonists in larvae lacking the JH-producing glands. Defining JH as a modulator of damage-induced delays could establish a novel mechanism to cope with tissue damage in holometabolous insects. In addition, it will establish a simpler insect model for studying body allometry when tissues are developing more slowly due to healing or regeneration after tissue damage.

135-3 ROSS, SA*; NIGAM, N; WAKELING, JM; Simon Fraser University, Burnaby, BC; *saross@sfu.ca*

A Modeling Framework to Evaluate Muscle Performance During Cyclic Contractions

Muscles serve several different functions, arguably the most important of which is to do work and generate power to move the skeleton. Hill-type models are ubiquitously used to understand and predict how muscles perform this function *in vivo*. However, current models suffer from limited accuracy, particularly under submaximal dynamic conditions that typically occur during daily activities. While attempts have been made to incorporate effects into these models that are typically neglected, such as history and tissue mass effects, their relative influence on muscle performance has yet to be evaluated under common contractile conditions and muscle parameters. The purpose of this study was to develop a modeling framework that consists of a damped harmonic oscillator in series with a Hill-type muscle actuator. The base muscle is composed of a contractile and a parallel elastic element, and can be modified to incorporate additional elements such as inertial mass. The parameters of the harmonic oscillator, such as the damping and stiffness, were chosen to allow for muscle lengths and speeds that reasonably reflect the behavior of muscle *in vivo*. The model can be geometrically scaled while preserving the relationship between the forces of the harmonic oscillator and the maximum isometric force of the muscle, which allows the effects of modifying properties of the muscle to be evaluated at different muscle sizes while controlling for the behaviour of the harmonic oscillator. Time-varying muscle activations cause transient muscle forces that in turn drive the dynamics of the harmonic oscillator, allowing muscle work-loops to be tested. Thus, this modeling framework can be used to evaluate the relative influence of history-dependent, internal mass and activation effects on the mechanical behaviour of muscle during cyclic contractions.

P1-10 ROSS, JA; California State University, Fresno; *jross@csufresno.edu*

A Model for Course Backward Design: Aligning Outcomes and Assessments with Bloom's Taxonomy and Vision & Change

Many of us work diligently to incorporate the recommendations of Vision & Change into our courses. For most topics, it is not possible to address all of the Core Concepts and Core Competencies. However, thoughtful mapping of course outcomes onto those concepts and competencies can help us identify and emphasize the most important aspects of the courses. Moreover, aligning the outcomes to Bloom's Taxonomy is meant to more explicitly link our expectations of student performance to the ways we assess student content understanding and the ability of students to accurately apply scientific principles. I will share a framework developed for the outcomes-based redesign of an upper-division majors biology lecture course to incorporate engaging case studies and active learning using mobile technology. By initially mapping student learning outcomes to Vision & Change and to Bloom's, generic summative assessment items were developed and shared with students at the start of the term. As backward design suggests, the class activities and case studies were explicitly tied to expectations of student performance, which helped students understand what and how to study. These changes led to several beneficial results, including improved attendance and in-class question-asking by students, and ultimately course improvements in student attitudes and grades.

10-2 ROTH, E*; DEORA, T; DANIEL, TL; ROTH, Eatai; Univ. of Washington; *eatai@uw.edu*

Exploring the Integration of Visual and Antennal Feedback in Flying Insects with a Braitenberg Vehicle Model

As an insect flies through its environment, it integrates sensory information across modalities to guide its trajectory; a broad repertoire of behaviors emerges from this confluence of parallel sensory processes as well as the physical interaction with the environment. In the laboratory, we often aim to isolate the sensorimotor computations that give rise to behaviors, measuring locomotor responses to individual sensory stimuli via constrained preparations. And at times, these laboratory findings do not jibe with naturalistic behavior, confounding our expectations and intuitions (e.g. tethered flies fixate a focus of expansion akin to flying backwards and arista-ablated flies recover from wind gust perturbations more rapidly than their intact counterparts). In his seminal cybernetics text "Vehicles", Braitenberg illustrates via simple robots (vehicles) that the interaction of reflexive sensorimotor circuits can yield seemingly complex or volitional behaviors. In this work, we leverage this bottom-up synthesis, drawing upon the literature of visual and antennal sensing to populate a vehicle model for flying insects. The model comprises a simulated sensory environment (visual scenes and airflow landscapes), visual and antennal sensorimotor computations that transform percepts into motor commands, sensory interactions between modalities (e.g. visually mediated head orientation and antennal positioning), and a physics-based flight model which integrates both self-generated flight forces and exogenous perturbations. Without any high-level decision making, this model demonstrates how the interaction between reflexive circuits proffers a parsimonious reconciliation for a broad behavioral repertoire and numerous (and sometimes confounding) experimental observations.

P2-20 ROUZBEHANI, M*; HORR, DM; IVANOV, BM; PAYNE, AA; VEGA, J; WANG, H; JOHNSON, MA; Trinity University; *mrouzbeh@trinity.edu*

Physiological Traits Predict Behavioral Activity in Female Lizards

Behavioral activity can be influenced by an animal's physiological characteristics, including traits such as energy storage, oxygen transport capacity, and, particularly in females, reproductive burden. In this study, we investigated the association between physiology and general activity in females of two species of *Anolis* lizards: *A. cristatellus* and *A. distichus*. In the lab, we performed open field tests to measure the latency and frequency of locomotor movements. We then measured each lizard's snout-vent length, body mass, fat pad mass, egg mass, liver mass, and hematocrit. We predicted that lizards would exhibit a trade-off between fat storage (in fat pads and liver) and egg mass, and that greater egg mass would reduce locomotor activity in female lizards. We also predicted that hematocrit levels would be positively associated with general locomotor activity. Our results showed that some aspects of the relationship between physiology and activity differed between the two species. In *A. cristatellus*, lizards with larger egg mass also had greater fat and liver mass, and displayed less activity, whereas in *A. distichus* egg mass was not associated with these measures. Yet in both species, lizards with a greater body condition index exhibited less locomotor activity, although hematocrit was not associated with behavior in either. The results of this study show that even among similar species of lizards, the relationship between energy utilization and behavioral activity may differ.

P3-161 ROZIN, R/E*; COST, I/N; HOLLIDAY, C/M; University of Missouri-Columbia; *rerqn8@mail.missouri.edu*

Feeding Biomechanics in Gallinaceous Birds and its Significance for Avian Cranial Evolution

A vital factor of the avian feeding apparatus is cranial kinesis: the mobility of bones within the skull about several key intracranial joints. The underlying patterns among avian jaw muscle and joint function, as well as their implication for ecology and evolution remain largely unknown. Gallinaceous birds vary in size and diet, but feed via pecking and have superficially similar skull morphologies. Thus we expect their jaw muscles and cranial joints to only differ relative to size and the forces loading them. To explore this relationship I built 3D models of five species of galliform and related anseriform taxa and quantified joint size and shape via 3D measurement tools to assess relationships between joint form and function in the complex 3D environment of the skull and found that muscle force and joint surface area expectedly increases as overall skull size does. So far the jaw, otic, and pterygoquadrate joints all scale isometrically, implying that they are under similar biomechanical regimens. However the palatobasal joint scales with positive allometry, suggesting that the relationship between the palate and the braincase may differ across taxa. Even across size and taxonomical differences, galliform cranial muscles have overall parasaggital orientation. This is the first quantitative, comparative analysis of cranial joint function in birds. Future studies will pair these findings with 3D joint force data to better understand the loading environment of the skull. Data from this study will lay groundwork for further studies in the biomechanics and evolution of cranial kinesis in other bird clades as well as in their extinct dinosaur ancestors.

84-4 ROZNERE, I*; SINN, BT; WATTERS, GT; The Ohio State University, West Virginia University; *roznere.1@osu.edu*

Transcriptomics in Conservation Biology: A Case Study with Freshwater Mussels

Recent advances in RNA-Seq technology and our ability to functionally annotate and study expression of thousands of genes in non-model species holds great potential for advancing the field of conservation biology. This project leverages transcriptomic methods to better understand how freshwater mussels (Unionidae) respond to environmental stressors, with the ultimate goal of improving conservation and management of North America's most endangered faunal group. A common conservation technique includes relocation into captivity for purposes such as research, propagation, and provision of temporary habitat. Relocation, however, often results in reduced growth rates and increased mortality. To better understand the physiological effects of relocation, we studied differential gene expression between wild and relocated, captive freshwater mussels. *Amblema plicata* individuals were relocated from the Muskingum River in Ohio to the Freshwater Mussel Conservation and Research Center. Gill tissue samples were collected from wild and captive mussels one year post-relocation. RNA was extracted and sequenced using 100 bp reads on the Illumina HiSeq 2500 platform. Transcriptomes were assembled using Trinity and differential gene expression was analyzed using the Bioconductor package edgeR. Transcripts were used as BLASTx queries against the National Center for Biotechnology nonredundant database. Functional annotation of transcripts using Gene Ontology terms was performed using Blast2GO. Significant differential gene expression was observed for over 1,000 genes between wild and relocated individuals. We discuss how expression levels of genes may be monitored in both natural and experimental settings to evaluate stress responses to a wide variety of environmental variables, and how such information can be used to improve conservation techniques.

135-7 RUBENSON, J.*; SALZANO, M.Q.; COX, S.M.; PIAZZA, S.J.; Penn State University; *jonas@psu.edu*

Developmental Plasticity of Musculoskeletal Structure and Locomotor Function in Guinea Fowl (Numida meleagris)

We explored whether animals exhibit musculoskeletal plasticity that correspond to different locomotor requirements during growth. Specifically, we tested the hypothesis that a growth period marked by either a) high-level exercise or b) minimal exercise (consisting primarily of standing) result in musculoskeletal modifications that are advantageous for power production or body-weight support, respectively. To test this, guinea fowl were raised from 2 - 26 wks in either 1) large pens that allowed spontaneous running and high-power perch jumps in addition to daily automated forced exercise (EX group, n=16) or 2) small pens that restricted movement to standing/walking (SED group, n=16). We found that optimal fiber lengths in the parallel-fibered iliotibialis lateralis pars postacetabularis were 25% longer in EX vs. SED ($p < 0.05$) post growth but that muscle cross-sectional area was 10% larger in SED ($p < 0.05$). No differences in muscle architecture were found in the pennate fibered gastrocnemius, but joint morphology indicated larger tendon moment arms at the ankle in the SED group post growth. These modifications favor power production in the EX group by minimizing force-length-velocity constraints and body weight support in the SED group by improving static joint moment generation. This interpretation was supported by greater mass-specific maximal jumping power in the EX group ($p<0.05$). Surprisingly, there was no effect on standing or running metabolic cost, including pilot data from animals that underwent sedentary growth with further local muscle disuse via botulinum toxin injections. These findings suggest that energy expenditure may be highly conserved compared to other locomotor performance criteria.

122-2 RUBIN, AR*; MAYERL, CJ; BLOB, RW; Auburn University, Clemson University; *amr0101@tigermail.auburn.edu*

Biomechanical Factors Influencing Successful Self-Righting in Upside-down Pleurodire Turtles

A wide range of circumstances can result in animals being turned over into an upside-down position, including falls, encounters with predators, and intraspecific combat. Self-righting from an upside-down position is a critical ability for rigid-bodied animals in particular, which are at risk of stranding, predation, starvation, and desiccation if they are unable to return to a right-side-up orientation. Among vertebrates, turtles are unique in their possession of a bony shell, which might present a significant barrier to self-righting. When upside-down, many turtles use their head and neck as a lever during efforts to flip back over. However, the mechanics of such head use has received little study, and the aspects of performance that correlate with successful versus unsuccessful righting are not clear. To evaluate how turtles use the head to right themselves, we synchronized high-speed video with force platform recordings to measure righting performance in the semi-aquatic pleurodire turtle *Emydura subglobosa*, a species that uses mainly the head, rather than limbs, to execute flips. Turtles were filmed from anterior and dorsal views after being placed on their backs with their head contacting a force plate. Our results indicate that successful flips were faster than failed attempts, and that in successful flips the head incurred greater ground reaction forces and turning moments. These data suggest that self-righting is highly dependent on both the position of the head during the self-righting attempt and the magnitude of force generated, and that a combination of factors must reach a critical threshold for a righting attempt to succeed.

14-2 RUDEN, RM*; ADELMAN, JS; Iowa State University; *ruden@iastate.edu*

Modulating disease phenotype in a wild songbird: a role for inflammation in tolerance and infectiousness

When an animal's immune system detects infection, it can kill the invading pathogen (resistance) or minimize per-pathogen reductions to host fitness (tolerance). Such responses not only have serious repercussions on individual health, but also impact the spread of disease through a population. While much research has focused on resistance, we understand little about the physiological causes or consequences of tolerance in wild animals. Finch mycoplasmosis is an infectious disease of North American songbirds caused by the bacterial pathogen, *Mycoplasma gallisepticum* (MG). It results in severe eye pathology, most striking in the house finch (*Haemorhous mexicanus*), that satisfies the cardinal signs of inflammation: swelling (tumor), erythema (rubor), heat (calor), and pain (dolor). Given the importance of inflammation in this disease, finch mycoplasmosis provides an ideal system to explore links among inflammation, tolerance, and pathogen transmission. Here, we report on two captive trials using non-steroidal anti-inflammatory drugs (NSAIDs) to dampen pro-inflammatory responses to MG infection. In our first study, 28 wild-caught, experimentally infected house finches were separated into three NSAID treatment groups: (1) no treatment, (2) oral meloxicam, and (3) topical flurbiprofen. Though both NSAIDs significantly enhanced tolerance, measured as the slope between peak pathology and peak pathogen load, flurbiprofen also enhanced resistance (i.e., reduced pathogen load). To test how tolerance changes infectiousness, we performed a transmission experiment comparing disease spread through flocks exposed to meloxicam-treated vs. wild-type birds experimentally infected with MG. We will discuss how these results link the mechanisms and consequences of tolerance in an ecologically relevant disease system.

21-6 RUDENKO, A; Goddard College MFA Interdisciplinary Arts; *ari.rudenko@gmail.com*

Prehistoric Body Theater: GHOSTS of HELL CREEK

Prehistoric Body Theater (PBT) is a transcultural art-science interface oriented dance company founded in Indonesia in 2015. PBT performances feature animal dance forms and theatrical narratives based on the latest paleontological models of the behavior and anatomy of extinct organisms and the prehistoric ecosystems within which they lived - exploring the implications of a deep-time perspective on human identity. PBT won the 2017 Bergstrom Award for Art-Science Interface, with advising paleontologists Greg Wilson (UW) and Dave Evans (ROM). The PBT method merges artistic foundations in Indonesian animal-form dance traditions and Japanese butoh theater, and incorporates consultation and character studies with leading paleontologists. GHOSTS of HELL CREEK (GoHC) is the first feature PBT production, presenting the story of the Hell Creek ecosystem - a prehistoric flood-jungle located in present day Montana, that captures a world from just before, during, and after the Chicxulub asteroid impact 66 mya, and the ensuing mass extinction of the dinosaurs and other exquisite fauna. The story follows a pack of *Acheroraptor temertyorum* on their journey into extinction in the wake of the impact, followed by the survival and rise of *Purgatorius unio*, and the subsequent evolution of the primates. GoHC is under development as a high-caliber international touring production featuring innovative choreographic, costume, and stage designs. The performance will feature an ensemble of primarily Indonesian contemporary dancers, celebrating diverse ethnic and artistic representation in the global arts+culture field. The GoHC tour offers additional programing, including a Roundtable on Deep-Time Identity, engaging participating artists and paleontologists on questions of tolerance regarding diverse global viewpoints on origin.

80-2 RUIZ, CA; PIMIENTA, MC; THEOBALD, JC*; Florida International University; *theobald@fiu.edu*

Pursuit flight patterns in long-legged flies

Long-legged flies of the genus *Condylostylus* (Diptera: Dolichopodidae) are small-sized (~5mm) aerial predators, commonly found in gardens and edges of forests in tropical areas. They keep their legs extended during flight and use them for steering and grabbing their prey. This high maneuverability is further enhanced by their extremely short times of reaction to a visual stimulus. As a result, predatory pursuits in these species are different from those reported previously for other flies and dragonflies. Using high-speed videography and 3D flight pattern reconstruction, we analyzed pursuit flight in *Condylostylus spp*. The flies were filmed while chasing targets moving in different patterns. We found that during a pursuit, the flies approached their target steadily via reactive navigation. Reactive maneuvering during a pursuit happened within 7-10ms of the target's steering. We also found that targets moving within 20 cm are usually approached and followed by the flies. Final approach and capture of the target happened only within 6cm of it and in response to target's evasive maneuvers. In contrast, targets that continued moving in a straight line were observed from that distance until the fly retreated. We discuss this pursuit strategy as a consequence of the specialization of this group of flies in hunting small, fast maneuvering, and swarming insects. Such a strategy where the interest of the predator is maintained by the evasive maneuvering if its target, has never been described before in flies and offers an excellent ground for comparison with aerial predators whose success is based on speed instead of maneuverability.

P1-219 RUMMEL, AD*; SWARTZ, SM; MARSH, RL; Brown University; *andrea_rummel@brown.edu*

A Comparison of the Thermal Sensitivities of Limb Muscles in a Small Bat Species and the Laboratory Mouse

Temperature has a profound effect on the contractile properties of muscles. Bats must maintain high locomotor performance in challenging thermal conditions, with convective heat loss across the flapping wings and radiative heat loss to the night sky. Presumably, critical wing muscles operate at relatively low temperatures but maintain adequate performance for flight. Distal wing muscles like the extensor carpi radialis longus (ECRL) in *Carollia perspicillata*, a small tropical fruit bat, may operate *in vivo* at 10-15°C below rectal temperature. Previously, we evaluated the isometric and isotonic contractile properties of the ECRL in *C. perspicillata* at 22, 27, 32, and 37°C, finding low Q_{10}s relative to other vertebrates, including mammals. Here, we perform isolated muscle preparations of a mouse muscle of similar size to the ECRL, the extensor digitorum longus (EDL) at the range of temperatures used previously and additionally at 40 and 42°C. We predict that Q_{10}s for rate-related processes in the mouse EDL will be higher than in the ECRL across the measured temperature range. Peak values of V_{max} and the fastest twitch and relaxation times were observed at 37°C in the bat ECRL and at 40 and 42°C in the mouse EDL. Both muscles declined in performance above those temperatures. Q_{10}s for each temperature interval are similar in the two muscles relative to each muscle's maximum temperature. This indicates that the ECRL has a lower temperature optimum (as opposed to a broader range of maximal performance) relative to the mouse EDL. This may indicate adaptation in the intrinsic properties of *C. perspicillata* wing muscles to habitually low temperatures in the wing.

24-6 RUPP, A*; SEVER, D; Univ. of Louisiana Lafayette, Southeastern Louisiana University; *aer0838@louisiana.edu*

Sexy Salamanders: Caudal Courtship Glands in Plethodontids that Lack Mental Glands

Salamanders in the family Plethodontidae exhibit a unique tail-straddle walk during courtship that can include the use of sexually dimorphic mental glands and caudal courtship glands. Mental glands are found in the skin of the lower jaw and caudal courtship glands are found in the skin of the dorsal base of the tail in some male plethodontids. Both are thought to increase female receptivity during courtship. While many studies focus on the variation and possible evolution of mental glands, few studies of caudal courtship glands exist and only the male morph A specimens of Eurycea wilderae are known to have caudal courtship glands without the presence of mental glands. This study analyzed museum specimens from genera known to lack mental glands and used standard histological methods to describe caudal courtship glands, or lack of caudal courtship glands. Presence of mature sperm in the Wolffian duct was also analyzed to determine sexual maturity and breeding status of males. Results show that there are caudal courtship glands present in males of species with no mental gland present, indicating the importance of these glands in courtship behavior. More data must be collected on caudal courtship glands before character optimization of these courtship glands on a phylogeny would be useful for studying the evolution of courtship behavior, but our data suggest that caudal courtahip glands may be driving the tail straddle walk in Plethodontidae.

P3-218 RUSSELL, AG*; CHANDLER, CH; SUNY Oswego; *aubrie.russell@oswego.edu*

XY or ZW? Sex-Reversal and Cytogenetics Capture Conflicting Pictures of Trachelipus rathkei Heterogamety

The advancement of sequencing technologies has made it clear that sex chromosome systems are diverse across taxa. Sex chromosomes are under the influence of unique selective regimes due to their uneven distribution between sexes, causing them to undergo frequent turnover. Terrestrial isopods are ideal organisms for the study of sex chromosome evolution because their adult sex is amenable to manipulation by a simple laboratory procedure. The implantation of a viable androgenic gland stimulates the male developmental pathway, causing juvenile females to develop into fully functional adult males. By crossing two genetic females and analyzing the sex ratio of their offspring, the sex chromosome composition of the parents can be determined. We have successfully achieved sex-reversal of two juvenile females of the species *Trachelipus rathkei*. Our experimental crosses using these individuals and un-manipulated females yielded 100% female progeny. Such a sex ratio has not been seen in *T. rathkei* broods from wild-bred females of the same population, and cannot be attributed to infection by the feminizing bacteria *Wolbachia*. These results indicate that this population of *T. rathkei* uses an XX/XY sex chromosome system, with homogametic females. A previous paper concluded that *T. rathkei* has a ZZ/ZW sex chromosome system, using cytogenetic evidence. In the future, we plan to replicate this procedure on *Porcellio scaber* individuals and expand our successes in *T. rathkei*. We also plan to extract and sequence RNA from sex-reversed individuals to search for evidence of dosage compensation in this species. Finally, this discovery will help us refine our search for the *T. rathkei* sex chromosomes and sex-specific markers using previously gathered PacBio data.

P2-106 RYAN, JF*; DEBIASSE, MB; Whitney Laboratory for Marine Bioscience, University of Florida; *joseph.ryan@whitney.ufl.edu*

Phylotocol: Promoting transparency and overcoming bias through publicly posted, a priori methodological protocols in phylogenetics

Inferring relationships between genes, genomes, and species is essential for a fundamental understanding of biology. Current best practices in phylogenetics do not include any formalized a priori decision making, which makes the process susceptible to confirmation bias. In clinical trials, where the outcomes of a study can lead to decisions that put human lives at risk, biases have been explicitly controlled for and transparency ensured by requiring an a priori protocol that outlines objective(s), design, methodology, statistical considerations, and study organization. Here we introduce phylotocol, a version-controlled a priori methodological procedure for providing a publicly available protocol for phylogenetic analyses. We have implemented the process for several projects, and besides promoting transparency and accountability in our process, phylotocol has led to several unforeseen advantages including: (1) serving as a training tool for junior researchers, (2) increasing productivity, (3) facilitating collaboration, (4) promoting efficient computational resource allocation, and (5) providing a detailed outline for a subsequent manuscript. We are currently seeking feedback on the concept and on our phylotocol template, which is based on a clinical trial protocol from the National Institutes of Health. Phylotocol is an easy to implement process that promotes transparency, reduces the risk of confirmation bias and facilitates project organization. A widespread increase in transparency is an important step in phylogenetics that will greatly accelerate our understanding of the evolutionary history of life.

S1-8 RYAN, JF*; HERNANDEZ, AM; SCHULTZ, DT; FRANCIS, WR; KOREN, S; SCHNITZLER, CE; MARTINDALE, MQ; HADDOCK, SHD; Whitney Laboratory for Marine Bioscience, St Augustine, FL, Monterey Bay Aquarium Research Institute, Moss Landing, CA, Monterey Bay Aquarium Research Institute, Moss Landing, CA, National Human Genome Research Institute, Bethesda, MD; *joseph.ryan@whitney.ufl.edu*

Revisiting gene content to resolve the phylogenetic position of ctenophores and sponges

The position of ctenophores and sponges on the tree of life is among the most contentious issues in biology. Historically, based on morphology and cell types, sponges were thought to be the sister group to all other animals while ctenophores, cnidarians, and bilaterians were believed to form a monophyletic clade. Early molecular phylogenies based on a small number of genes (e.g. 18S and COI) supported the former but placed Placozoa as the sister group to Cnidaria and Bilateria. Beginning with a landmark study in 2008 by Dunn and colleagues, the majority of animal phylogenomic analyses have recovered Ctenophora as the sister group to the rest of animals. To test whether these phylogenomic results are spurious or reflect true relationships, we have applied gene content as a phylogenetic marker. In addition to being largely independent from sequence-based alignments, gene-content phylogenies provide reduced effects of unequal rates of evolution and fewer ambiguous signals than sequence data. Like sequence-based phylogenomics, gene-content analyses afford large datasets (>20,000 characters) and objective and repeatable matrix construction. In the current study we augment the gene content matrix from Ryan et al. (2013) with a substantial amount of new data from several ctenophore, sponge, and outgroup species in an attempt to robustly solve the relationships between the major animal lineages.

P2-30 RYAN, TA*; VITOUSEK, MN; Cornell University; *tar87@cornell.edu*

Using a Large-scale Database to Understand Impacts of Life-history and Phylogeny on a Known Physiological Relationship: Re-examining Corticosterone and Molt in Birds

Molt, or feather growth, is an important part of the annual life cycle of birds. Birds must replace feathers at regular intervals, but considerable variation exists in molt strategy, sequence, and duration. Feather quality and growth rate have been demonstrated to be adversely affected by corticosterone, the main glucocorticoid responsible for the stress response in birds and a key regulator of energy levels and metabolism. CORT has been shown to circulate at the lowest annual levels for many birds during regular periods of molt, perhaps to allow for the growth of good quality feathers. However, periods of molt can occur simultaneously with other life history stages, such as migration or breeding, wherein relatively higher levels for baseline and stress-induced CORT may be adaptive. Here we seek to understand variation in this hormonal association with a life-history trait and, particularly, how such variation is explained by phylogeny and association with other life-history traits. Specifically, we use HormoneBase, a large-scale database of hormone concentrations across vertebrates, to re-examine variation in CORT levels during molt and investigate how life-history traits, such as molt strategy, and phylogeny, explain variation in CORT baseline and stress levels during periods of molt. We predict a greater degree of down-regulation of CORT for birds that have shorter molt period duration and relatively less molt-period overlap with life-history stages in which relatively high CORT may be adaptive. We further predict greater down-regulation of CORT for birds that migrate following molt, as migrants are subject to additional selective pressures favoring quick growth of strong feathers.

6-6 RYERSON, WG*; TAN, W; Saint Anselm College; *wryerson@anselm.edu*

Effects of long-term captivity on strike performance in 5 species of snakes

The captive breeding and care of reptiles is extremely commonplace throughout North America, with important roles both economically and in conservation. As a result, there are many established guidelines and protocols for raising and breeding reptiles in captivity. However, little is known about how these programs alter the behavior of individuals kept in captivity long-term, and what the long-term consequences may be. As a first attempt to quantify some of these behavioral changes, we used high-speed video to examine striking in 5 species of long-term captive snakes to see how captivity has altered the performance of the strike. We chose 3 species with an extensive history in the exotic pet trade: ball pythons (*Python regius*), red-tail boas (*Boa constrictor*), and California kingsnakes (*Lampropeltis californae*). Our other 2 species, the northern copperhead (*Agkistrodon contortix*) and eastern rat snake (*Pantherophis alleghaniensis*) are not commonly bred in captivity and in our samples first-generation captives. Strike performance was species-specific. The northern copperhead and red-tail boa exhibit strike velocities, accelerations, and kinematic profiles that closely match the available literature on strike performance in other snakes. The other three species showed significantly lower strike velocities, strike accelerations, gape angle, strike distances, and angular accelerations. Performance was not correlated with body size, history of captivity (long-term vs first-gen), foraging mode (ambush vs active) or prey size. The mechanisms behind these patterns remain unclear, and we suggest several potential avenues for further research.

P1-217 RZUCIDLO, CL*; MORAN, CJ; GERRY, SP; Fairfield University; *caroline.rzucidlo@student.fairfield.edu*

Locomotor Performance and Muscle Physiology of Tautog (Tautoga onitis)

Residing in the North-West Atlantic, tautog are one of the northern most species in the family Labridae. As water temperatures cool tautog migrate offshore to their wintering habitats where temperature is constant in deep water. Previous work with cunner, a related species, demonstrated that muscle function was inhibited at cold temperatures. We studied the impact of acclimation temperature (5, 10, 15, 20°C) on steady swimming and pectoral fin muscle function in tautog. We hypothesized that muscle acclimated at cold temperatures will produce less power than muscle acclimated at warm temperatures. Additionally, we hypothesized that twitch contraction and relaxation times would increase with decreasing temperature. To address these hypotheses, we acclimated tautog (n=5) at each temperature for a minimum of two weeks. We performed steady swimming experiments, then removed the abductor superficialis and performed muscle kinetic tests and standard workloop protocols. Fish acclimated at warm temperatures (15 and 20°C) were able to sustain higher swimming velocities. At cold temperatures (5 and 10°C) the pectoral fin abductor muscles were slower to contract and relax, displaying inhibited muscle function. Additionally, power output increased with increasing temperature. Decreased swimming and muscle performance suggests that tautog migrate offshore to a thermally constant environment, avoiding further cooling in inshore habitats.

P3-230 SAATHOFF, MM*; ROOP, S; PRUETT, J; HOEKSTRA, L; JANZEN, FJ; ADDIS, EA; Gonzaga University, Auburn University, Iowa State University; *msaathoff@zagmail.gonzaga.edu*

Variation in Maternal Investment across the Range of the Painted Turtle (Chrysemys picta)

Ecological variables affecting reproductive output often vary across a species' range. In an effort to determine how maternal investment may vary across the range of the Western painted turtle (*Chrysemys picta*), we compared nests from populations of turtles from the northwestern (Idaho) and midwestern (Illinois) regions of their range. We measured maternal investment by measuring the size and mass of eggs, the number of eggs per clutch, and the number of clutches per mother. We found that females in Idaho lay more and larger eggs per nest than those from Illinois, but Illinois mothers lay more clutches. This may be because the laying season in Illinois is longer or the possible presence of more predators in Illinois. However, the influence of maternal size on clutch number is relatively consistent between the two locations. Egg mass and clutch size increase with maternal size in both locations, but in the Idaho population there is stronger correlation between maternal size and egg number than in Illinois. Additionally, later clutches have both fewer eggs and smaller eggs in both locations. Thus, it seems that larger mothers lay more eggs, and larger eggs, but the strength of this correlation may vary across the species range.

P2-247 SABOL, A*; SOLOMON, N; KEANE, B; DANTZER, B; Univ. of Michigan, Miami Univ.; *sabola@umich.edu*

Social network bonds related to mating strategy, parentage, and the microbiome in prairie voles (Microtus ochrogaster)

The social interactions that make up an animal's social network may have important impacts on their behavior and physiology. However, the number and strength of these social relationships may be influenced by the ecology of the species and/or the behavior of an individual and this in turn can affect the individual's behavior, physiology, and fitness. Little is currently known about these bidirectional feedbacks between social bonds, physiology, and behavior. In prairie voles (*Microtus ochrogaster*), the mating strategy of individuals varies from polygynous to socially monogamous, with a varying level of genetic monogamy among socially monogamous pairs. This variation may lead to a difference in the number of contacts a vole has with opposite-sex conspecifics and/or the strength or duration of each of these social contacts. We predicted that polygynous individuals would interact with more opposite-sex conspecifics than socially monogamous individuals. Within socially monogamous pairs, we predicted the higher the level of genetic monogamy that individuals exhibit, the fewer social interactions they would have with opposite-sex individuals. We then compared the number and strength of these social bonds with opposite-sex individuals to the number of offspring that individuals produced and the diversity of their oral microbiome. To do this, we tracked the interactions of prairie voles in semi-natural field enclosures through an automated RFID antenna system, radio telemetry, and live-trapping to measure the number and strength of social bonds between opposite-sex voles. We also collected oral microbiome samples to track changes in each vole's microbiome. This study further enhances our understanding of the bidirectional nature of the relationship between social bonds, fitness, and ecology in a system with variable mating strategies.

P1-227 SABOTIN, R*; TRAN, T; FASSBINDER-ORTH, C; Creighton University; *ryansabotin@creighton.edu*

Vitellogenin Expression in Honey Bees (Apis mellifera): How Viral Infections Influence Honey Bee Physiology

Honey bees (*Apis mellifera*) play a vital role in pollinating both agricultural crops and wild plants. However, over the past several decades honey bee populations have been declining in a phenomenon known as Colony Collapse Disorder (CCD). The ectoparasitic mite, *Varroa destructor*, has been a large contributor to CCD, as it is known to transfer viruses that may ultimately lead to colony loss. As previously shown, varroa mites enhance the effects of these infections as well, causing abnormalities in bee physiology and behavior. Looking specifically at physiology, our project analyzed how a dicistrovirus, cricket paralysis virus (CrPV), affects the gene expression of vitellogenin. Vitellogenin is linked with regulatory behaviors; low amounts promote frantic foraging behaviors that may aid in CCD. Honey bees were divided into the following groups: No injection control, Vehicle injection control, CrPV, or *V. destructor* protein + CrPV (VP+CrPV). Bees were halved and used in both viral quantification using $TCID_{50}$ assays and gene expression analysis using quantitative reverse transcription PCR (RT-qPCR). Vitellogenin mRNA was quantified alongside CrPV viral RNA with the use of β-actin as a reference gene. VP+CrPV exposed bees had an 89.2% higher level of viremia compared to CrPV-infected bees only, according to $TCID_{50}$ results. Control bees exhibited no viremia. Relative vitellogenin expression was significantly lower in the VP+CrPV and CrPV infected bees compared to control bees. These results uncover a potentially substantial physiological relationship between viral disease and vitellogenin that may inform us about some of the underlying mechanisms of colony collapse disorder.

P2-234 SACHDEVA, V*; ZHAO, D; REVZEN, S; University of Michigan; *shrevzen@umich.edu*

Cockroaches always slip a lot

For humans and large animals, slipping while running can be catastrophic and there are many well documented slippage avoidance strategies. However, while there is no obvious critical survival reason for small animals to avoid slipping, computational models of multi-legged locomotion still assume non-slip conditions in stance. We have found non-slip constraints to severely impede the performance of some of our hexapod robots, and therefore set out to test if these non-slip assumptions apply to the animals that inspired their designs. We investigated slipping in *Blaberus discoidalis* cockroaches (N=7, 2.66+/-0.8 g (mean,sd)) running at 15-77cm/s (51+/-10 cm/s (mean,sd)). We found that front, mid, and hind legs slipped 21.%, 18.%, 20.% of their total travel distance in the lab frame. We separated video frames into quintiles sorted by turn rate and used Mann-Whitney U tests to compare median turn rate versus slipping distance. We found that median slippage distance was not significantly different in the turning rate bins. Our results suggest that slipping is a routine part of cockroach locomotion, and is independent of turning speeds.

P3-245 SALAGUINTO, TC*; RIVERA, V; GONZALEZ, VH; RIVERA, JL; TSCHEULIN, T; PETANIDOU, T; HRANITZ, JM; BARTHELL, JF; Whitman College, Walla Walla WA, University of Puerto Rico, Rio Piedras, University of Kansas, Lawrence, University of the Aegean, Mytilene, GREECE, Bloomsburg University of Pennsylvania, University of Central Oklahoma, Edmond; *taylor.salaguinto@hotmail.com*

Nectar Dynamics of Convolvulus arvensis in the Mediterranean Ecoregion

We analyzed natural nectar dynamics, removal effects, and floral visitors of *Convolvulus arvensis* on the eastern Greek island of Lesbos. To determine nectar reward to pollinators, we measured nectar dynamics of individual flowers, in anthesis, in June and July at several field sites. Nectar flow and standing crop differed among collection times and different sites. In general, flowers produced the most nectar volume at the beginning of the day, which gradually decreased thereafter. Nectar flow and standing crop available to pollinators differed in their responses to visitation. Nectar flow displayed interactive effects between Site and Time, whereas standing crop displayed a Site effect and a Time effect. Nectar flow was not consistently higher than standing crop, as we hypothesized. However, we correlated temperature, pollen availability, and visitation rates of primary pollinators as factors affecting nectar reward. A post-hoc hypothesis for the different response of nectar flow and standing crop to visitation is nectar reabsorption by *C. arvensis*. *Systropha curvicornis* and *Lasioglossum malachurum* primarily visited *C. arvensis* as abundant pollinators during our studies. In a nectar removal experiment, *L. malachurum* harvests the pollen and not the nectar of *C. arvensis* but the specialist, *S. curvicornis*;, harvests both pollen and nectar of *C. arvensis*. Therefore, the foraging behavior of these two species should be taken into consideration when examining the nectar dynamics of *C. arvensis* in the Mediterranean ecoregion.

106-6 SALAS, H K*; SAYAVONG, N; GUNDERSON, A R; STILLMAN, J H; TSUKIMURA, B; California State University Fresno, San Francisco State University, San Francisco State University; *hazz332@mail.fresnostate.edu*
Effects of thermal stress on Vitellogenin levels in the hemolymoh of the anomuran crab Petrolisthes cinctipes
Intertidal organisms, like the porcelain crab, regularly experience thermal stress. *P. cinctipes* inhabits the upper-mid intertidal zone and is often exposed during low tides. Increased abiotic stressors may interfere with many aspects of this organisms' physiology, including reproduction. Reproductive activity can be measured through the quantification of the yolk protein vitellogenin (Vg), found in hemolymph. ELISA for *P. cinctipes* allowed for quantification of Vg in hemolymph. Monthly Vg sampling of *P. cinctipes* revealed depressed reproduction around the summer solstice. Reproduction may be dependent on environmental variables such as temperature or day length. To examine this, *P. cinctipes* were collected monthly over the course of a year. After a pre-treatment hemolymph sample, crabs underwent treatment to examine effects of day length and temperature. Following two-weeks of exposure, a second hemolymph sample was drawn. Pre and post treatment hemolymph samples were analyzed for Vg levels by ELISA. Crabs collected near the summer solstice sustained low levels of Vg after exposure to thermal stress. Long day thermal stress conditions caused Vg production to decline in crabs collected during the winter solstice. Additionally, this species was found to respond to changes in the lunar cycle for Vg regulation. These data suggest that *P. cinctipes* rely on multiple environmental cues in regulating reproduction, and minute changes in environmental conditions could interfere with this physiological process.

P3-25 SALAZAR, B*; DUNCAN, A; BRANDLEY, N; Colorado College, College of Wooster; *b_salazar@coloradocollege.edu*
The conspicuousness of band-winged grasshoppers to predators and conspecifics
In band-winged grasshoppers (subfamily Oedipodinae), the variety of hindwing colors --- ranging from blue to red --- is both striking and unexplained. Hindwing color can vary both within and between species. However, the functional significance, if any, of this variation is unknown. Notably, the colorful hindwings are revealed only in flight, and remain hidden in stationary individuals. Although experimental evidence is lacking, this flash of color has been proposed to 1) startle potential predators, 2) to signal the quality of a potential mate, and 3) to enhance species recognition. To elucidate their potential function(s), here we measure the spectral and spatial characteristics of the hindwing patterns in 6 different band-winged species. We then model how an avian predator or potential mate might view grasshopper wings at behaviorally relevant distances. This data suggests that there is a rapid change in conspicuousness as a grasshopper moves from rest to flight regardless of the color vision of the receiver. However, there is little within species variation in coloration or wing patterning. Our results indicate that while hindwings 1) may function as a protean defense against avian predators, 2) it is unlikely that they serve as a signal of mate quality, although, they 3) may deliver enough information for species recognition. This research helps to elucidate evolutionary relationships leading to the diversification of behavior, visual systems, and coloration within band-winged grasshoppers.

81-4 SALCEDO, MK*; COMBES, SA; MAHADEVAN, L.; Harvard University, Univ. of California, Davis; *maryksalcedo@gmail.com*
Active hemolymph flow in insect wings: characterization of uniform, bi-directional and pulsatile flow in a wing network
Hemolymph is pumped throughout an insect's body and appendages by peristaltic contractions of the dorsal aortic vessel, and in larger insects, with the assistance of accessory pulsatile organs. Continuous flow is necessary for the transport of nutrients, removal of waste, and support of an active immune system. Unconstrained by a vascularized network until it enters the wing, hemolymph actively flows into the wing and its system of veins with the assistance of a pulsing wing "heart." The veins transport hemolymph, contain trachea and nerves, and provide structural support for the wing. While many structural aspects of insect wings have been characterized, hemolymph dynamics and the physics mediating this flow within the wing and its pumping organs remain largely unknown. We observed these hemodynamics within live adult American Bird Grasshoppers (or commonly American Locust), *Schistocerca americana* (Family: Acrididae). This genus, known for occasional swarming, is a competent and energetic flier with a wing span of ~5 cm. We tracked fluorescent particles within the wing, pulsatile organs at the wing hinge, and dorsal abdominal segments to determine flow direction, Reynolds number and pressure distributions within the wing. Contrary to suggestions in previous literature, we present evidence of uniform, pulsatile, and bi-directional flow in the longitudinal veins and cross veins, across the span and chord of both fore and hind wings. These results highlight the importance of the pulsatile organs and of fluid flow through insect wing veins, and suggest that fluid transport in the wings may play an important role during flight.

S9-4 SALIN, Karine*; VILLASEVIL, Eugenia; ANDERSON, Graeme; SELMAN, Colin; CHINOPOULOS, Christos; METCALFE, Neil; IFREMER, France, University of Glasgow, UK, Semmelweis University, Hungary; *Karine.Salin@ifremer.fr*
Mitochondrial responses to environmental change: mechanisms and consequences.
Mitochondrial coupling represents an animal's capacity to convert its resources into ATP. Interpretations of mitochondrial coupling depend on whether it is calculated as the respiratory control ratio, RCR (ratio of mitochondrial respiration supporting ATP synthesis to that required to offset the proton leak) or as the amount of ATP generated per unit of oxygen consumed, ATP/O ratio. The question of how flexibility in mitochondrial function (i.e. in rates of respiration to support ATP synthesis and offset leak, and in rate of ATP synthesis) affects these indices of coupling has never been considered in depth. Furthermore, little is known of whether the RCR and ATP/O ratio vary in parallel, either among individuals or in response to environmental conditions. Using data from brown trout *Salma trutta* we show that experimental conditions affect mitochondrial coupling, but the pattern observed depends on the measure chosen: a reduction in food availability was associated with an increase in RCR but a decrease in ATP/O ratio in liver mitochondria. Moreover, there was a negative correlation across individuals held in identical conditions between their RCR and their ATP/O ratio, mostly due to dramatic differences in the amount of oxygen required to support ATP synthesis. These results show that the choice of index of mitochondrial coupling can produce different, even opposing, conclusions about the capacity of the mitochondria to produce ATP. Consequently, we encourage investigators to be more specific in their interpretations of these indices, and ideally to validate which index actually predicts animal performance.

S9-1 SALIN, Karine*; HOOD , Wendy; IFREMER, France, Auburn University, USA; *Karine.Salin@ifremer.fr*

Introduction

Our goal in organizing this symposium is to bring together researchers interested in the links between mitochondrial properties and key traits that contribute to individual variation in fitness, such as growth, reproductive performance and longevity. By encouraging talks that combine physiological ecology, evolutionary genomics, gerontology and metabolic biochemistry we seek to bridge the gap between physiologists, ecologists and evolutionary biologists. We organised the session around 3 key inter-related topics: energy metabolism, oxidative stress, and mitonuclear interactions. Conceptual overlap between talks and topics are encouraged. The main symposium include ten presentations by a diverse group of invited speakers who have introduced cutting-edge mitochondrial function measurements to ecological and evolutionary biology. The companion oral and poster session will give other SICB delegates the opportunity to present at the meeting. Our primary aim in organizing this symposium is to bring together researchers who would not otherwise interact. We acknowledge financial support from Society of Integrative and Comparative Biology (DCPB and DCE), the National Science Foundation, The Canadian Society of Zoology and the Company of Biologists.

64-8 SALINAS-SAAVEDRA, M*; MARTINDALE, MQ; Whitney Laboratory for Marine Bioscience, University of Florida ; *mssaavedra@whitney.ufl.edu*

Is the maintenance of cell polarity coupled to stable cell-cell adhesion? Insights from early branching metazoan embryos.

Epithelial cells of bilaterian animals are polarized along the apico-basal axis by the stabilization of adherens and septate junctions, respectively. Previous studies obtained in the lab, using embryos of the cnidarian *Nematostella vectensis*, suggest that this mechanism of polarization could have already been present in the most common ancestor of Bilateria and Cnidaria: While adherens junctions stabilizes the localization of the aPKC/Par complex at the apical cortex of the cells, septate junctions stabilizes Lgl and Par-1 at the basolateral cortex of the cells. Interestingly, even though cadherins (a component of adherens junctions) are present in the genome of the ctenophore *Mnemiopsis leidyi*, the latter does not possess the components necessaries to assemble the septate junctions that are present in bilaterian animals. Concordantly, in *M. leidyi* embryos Par-6 localizes to the apical cortex but Par-1 remains cytoplasmic, different from what we have described for *N. vectensis* embryos. This data suggest that the absence of septate junctions may be related to this localization pattern. To test this hypothesis we disassembled the formation of septate junctions by using CRISPR/Cas9 to knock down Contactin (a component of septate junctions) in *N. vectensis* embryos, and analyzed the localization of Par-1 and Lgl by immunofluorescence. In addition, using a ctenophore-specific ß-catenin antibody and a GFP-labeled mRNA reporter as markers for adherens junctions, for the first time we describe its localization during the *M. leidyi* embryogenesis, and compared it to *N. vectensis* and bilaterians embryos.

S10-10 SALMóN, Pablo; WATSON, Hannah; NORD, Andreas; HERRERA-DUENAS, Amparo; ISAKSSON, Caroline*; Lund University; *Caroline.Isaksson@biol.lu.se*

Oxidative stress physiology and survival in the urban environment

Urbanisation is expanding across the globe, and with urbanisation comes a long list of environmental challenges that birds either need to deal with or flee from. These challenges are for example increased air pollution, human disturbances, along with habitat fragmentation. Many species completely disappear from the urban landscape, whereas other species stay or even move into the new urban environment. But how well do they actually cope with the urban environmental stressors? Is urban life associated with hidden physiological costs? Or are their physiological systems efficient in protecting them from these multiple external stress factors? Previous studies have shown that air pollution triggers the antioxidant defences of most animals. However, the magnitude of the response and consequently, the physiological damages seem to be species, life-stage and context-specific. In addition, the links between physiological markers and survival are rarely investigated. Here we use a cross-fostering design to, *first*, disentangle genetic effects from direct environmental influences on oxidative stress physiology during postnatal development, a life-stage known to be sensitive to external stress. Using urban and rural nest box populations of great tits (*Parus major*), half-broods were swapped (day 3) between the environments and blood-sampled at day 15. *Secondly*, we examined whether oxidative stress status predicts survival to the subsequent breeding season and whether the relationship differed between habitats. We discuss the capacity of avian physiological systems to cope with urban environmental stress and the associated costs of being reared in the city.

129-5 SAMSON, JE*; RAY, DD; GARNIER, SJ; PORFIRI, M; MILLER, LA; UNC Chapel Hill, NJIT, NYU; *julia@unc.edu*

Using computer vision tools to detect collective pulsing patterns in xeniid corals

Xeniid corals form a special group within the soft corals (Alcyonacea) with some of their members displaying a unique pulsing behavior. Within a pulsing coral colony, each individual polyp actively pulses, increasing the local mixing and enhancing nutrient and gas exchange. When looking at a colony of pulsing corals, the first questions to come to mind are whether this behavior is coordinated and how. Our hypothesis is that the pulsing behavior is coordinated, and that the coordination is in part influenced by local flows sensed by the individual polyps, and in part influenced by internal (neural) signals between polyps. To test this hypothesis, we used ISOMAP, a computational algorithm designed to find patterns in video data. We also computed the transfer entropy between any given pair of polyps in a colony to quantify the transfer of information between members of a same colony. With this data, we are able to start investigating how patterns of collective pulsing behavior affect local flow and mixing around coral colonies.

P3-126 SAMUELS, TJ*; PHILSON, CS; FOLTZ, SL; RAY, A; DAVIS, JE; Radford University; *tsamuels3@radford.edu*

The PASSER Project: Inducing Neophobia though Presented Stimuli via a Computer Enabled Feeder

With changing seasons comes new abiotic and biotic factors that affect bird behavioral and physiological profiles. Identifying relationships between neophobia and stress in different species of birds through the seasons, and through introduced stimuli, can indicate the variation of stress levels under these conditions. By displaying stimuli to an individual bird during a feeding event at a PASSER smart feeder, we can observe how behavioral responses are altered throughout the changing seasons. We hypothesize that birds' responses to these induced neophobic stimuli will vary in relation to both seasonal and variable weather conditions. This study uses a computer-enabled automated feeding device equipped with a monitor that displays a variety of images when birds approach the feeder. Images include a variety of stimuli, including common predators, conspecifics, heterospecifics, and novel stimuli. Though these presentations of stimuli induced varying levels of neophobic responses, responses were still correlated to the abiotic and biotic conditions at the time of display. We monitor behavioral responses via recorded video collected by the feeders. To determine the level of response under all presented stimuli, we measure the length of feeding event, noises produced by the bird, and signs of defense before flight. This data shows how birds' behaviors are alerted and if abiotic and biotic factors matter. In this poster, we will describe our methods and results, and discuss implications of our findings and techniques for future studies.

P3-252 SAN JUAN, PA*; HENDERSHOT, JN; DAILY, GC; FUKAMI, T; Stanford University; *psanjuan@stanford.edu*

Land use change influences avian gut microbiomes

Land use change can decrease animal biodiversity, but its impact on their gut microbiome is not well understood. We sought to quantify this effect on bird microbiomes in a Costa Rican landscape that contained habitats ranging from pristine forests to coffee plantations using 16S rRNA sequencing. In this landscape, we collected 346 fresh fecal samples from six common species of insectivorous birds (clay-coloured thrush, *Turdus grayi*; Swainson's thrush, *Catharus ustulatus*; orange-billed nightingale-thrush, *Catharus aurantiirostris*; yellow warbler, *Dendroica petechia*; rufous-capped warbler, *Basileuterus rufifrons*; and buff-throated saltator, *Saltator maximus*) at sites across a land use gradient. The most dominant bacterial phyla across the six species of birds included Proteobacteria, Firmicutes, and Bacteroidetes. Diversity indices showed no significant difference among habitat types or bird species identity, suggesting that land use change or host identity may not affect gut microbial diversity. However, microbial species composition was significantly associated with bird species identity, with four of the six bird species (yellow warbler, buff-throated saltator, Swainson's thrush, and clay-coloured thrush) having distinct patterns. In addition, we found significant clustering of microbial communities by habitat type in two of the six birds, suggesting that the effect of land use change on bird gut microbes may be host-specific. Overall, our data suggest that both host species identity and habitat type can influence gut microbial composition, but that host identity may affect microbial composition more strongly than habitat type.

P2-145 SANCHEZ, K*; SEITZ, M; TIMKO, S; THOMPSON, L; GRAYSON, K; Univ. of Richmond, VA; *mariakhaela.sanchez@richmond.edu*

Population Structure of the Red Backed Salamander near the Southern Range Edge

Terrestrial salamanders can be an underappreciated component of forest ecosystems, yet comprise a high proportion of vertebrate biomass in these habitats. Eastern red backed salamanders (*Plethodon cinerus*) are widely distributed throughout northeastern North America, with the southern portion of the range extending to Virginia and North Carolina. Most studies have examined the ecology of these terrestrial salamander populations in cool, mountainous regions, but few have studied this species in warmer, lower altitude portions of their range. In this study, count and mark-recapture survey methods of artificial cover board plots were used to regularly monitor salamander activity in an urban park in Richmond, VA. Estimates of population density and space use for each plot were generated as part of the Salamander Population and Adaptation Research Collaboration Network (SPARCnet). We found differences in density and movement between juvenile and adult salamanders, and we examined how variation in plot density changes the composition of surface active salamanders. Overall we observed seasonal differences in activity compared to other portions of the range, with greater winter surface activity and a longer suspension in summer activity for our Richmond population. Red backed salamanders are an important indicator species for forest ecosystems due to their sensitivity to changing environments. Further work in this system will contribute to the SPARCnet range-wide data set and a better understanding of adaptation to changing climates in terrestrial salamanders.

101-3 SANCHEZ, ER*; TRACY, CR; TRACY, CR; California State University, Fullerton, Boyd Deep Canyon Desert Research Center, University of Nevada, Reno; *emilysanchez@csu.fullerton.edu*

Do Sex and Season Affect Thermoregulatory Behaviors of the Common Chuckwalla (Sauromalus ater)?

There is extensive literature on intraspecific variability of thermoregulation due to habitat, temperature availability, and seasonality, but fewer studies focus on variability due to sex. Sex-specific thermoregulatory strategies may affect relative fitness disproportionately, driving different responses to environmental changes (e.g., climate change). The common chuckwalla (*Sauromalus ater*) is a great model for investigating sex differences in thermoregulation because it is sexually dimorphic in behavior; males hold territories that they actively patrol and defend. We hypothesized that male and female chuckwallas thermoregulate to the same temperatures and to the same extent, but that males spend more time thermoregulating outside of refuges (e.g. to defend territories) compared to non-territorial females. Body temperatures of free-ranging adult chuckwallas were continuously recorded from May to early July 2016, as were operative temperatures in crevices and above-ground basking sites that provide context for lizard body temperatures. We compared the effects of month and sex on the average time chuckwallas selected body temperatures above, below, and within their preferred temperature range (34-39 °C) for May-July. Chuckwallas on average spent more time below 34 °C in May, and above 39 °C in July. This reflects temporal and spatial changes in available suitable operative temperatures. On average, females in June spent significantly more time at body temperatures below preferred range compared to males. This may reflect different late-season reproductive priorities, with males seeking final mating opportunities aboveground, and females seeking underground nesting sites.

P3-237 SANCHEZ, N*; SPEISER, DI; BOGGS, C; University of South Carolina; *ns5@email.sc.edu*

The Visual Ecology of the Mormon Fritillary, Speyeria mormonia, Across an Elevational Gradient

Climate change may affect the visual ecology of butterflies by altering temperature and food availability, which are environmental factors known to influence the development of morphological traits important for mate selection in these animals. These traits include eye size, as well as sexually dimorphic wing patterns and colors. To investigate how temperature variation may impact butterfly visual ecology, we collected *Speyeria mormonia* from different sites across a temperature gradient and studied the natural variation of two of their sexually dimorphic traits. The dorsal sides of wings from male and female *S. mormonia* are similar in color, but the ventral sides of their forewings are dimorphic: females have an orange patch that is absent in males. The eyes of *S. mormonia* are also sexually dimorphic: the eyes of males have larger absolute and relative surface areas than those of females. We collected *S. mormonia* from five different elevations, spanning approximately 2000 ft., within the Rocky Mountain Biological Laboratory in Colorado. We used image-analysis software and reflectance spectroscopy to measure the wing color of individuals from the different sites. We studied the interaction between elevation and a study population's wing color or eye surface area. We found that female *S. mormonia* from higher elevations generally have redder patches of color on their ventral forewings than those from lower elevations. We also found that *S. mormonia* from an elevation of 11,000 ft. had the smallest average relative eye surface area (0.25 mm^2/mm) while those at 9,400 ft. had the largest (0.31 mm^2/mm). We suspect that the morphological differences present across elevations may impact mating interactions. This study may ultimately hold implications on how climate change affects the visual ecology of *S. mormonia*.

P3-114 SANDERS, EJ*; BUBAK, AN ; RENNER, KJ; SWALLOW, JG; University of Colorado Denver, University of Colorado Denver, Anschutz Medical Campus, University of South Dakota; *erin.sanders@ucdenver.edu*

Mating-Receptivity in Female Dipterans is Mediated by Daily Fluctuations of Dopamine Levels

Dipterans, like vertebrates, are subject to circadian rhythms. Circadian rhythms can cause physiological changes that lead to differences in behavioral responses throughout the day. These physiological changes include fluctuations in monoamine levels, such as dopamine. Invertebrates, like stalk-eyed flies (*Teleopsis dalmanni*), are a useful model for studying the function of conserved mechanisms, like monoamines, that are also seen in vertebrates. We designed a circadian rhythm study in which flies were sacrificed every four hours and used HPLC with electrochemical detection (ED) to detect changes in whole-brain levels of dopamine, serotonin, and octopamine throughout the day. Octopamine and serotonin stayed relatively level throughout the day in both males and females. Female stalk-eyed flies were found to have a spike in dopamine levels from 6 to 10 pm, which is when they tend to roost, while male levels stayed stable. This spike was not seen at other times throughout the day. We hypothesized that this spike in dopamine would lead to increased mating receptivity in females. To test this, we administered 3-Iodo-L-tyrosine 97%, which inhibits the enzyme Tyrosine Hydroxylase and decreases the synthesis of L-Dopa, to knock down dopamine globally in female flies. Both control and treated females were isolated from males, who were also isolated from other females, for three days while the drug was being administered. Then mating receptivity was assessed, recorded, and scored. HPLC with ED and Immunohistochemistry were used as validation methods to ensure that dopamine was knocked down. The results supported the hypothesis that a circadian increase in dopamine plays a significant role in mating receptivity in female stalk-eyed flies.

P3-67 SANDERS, TL*; WOLF, SE; ROSVALL, KA; Oklahoma State University, Indiana University; *tiana.sanders@okstate.edu*

Telomere Length Predicts Life History Trade-Offs in Wild Female Tree Swallows Tachycineta bicolor

Life history trade-offs influence how organisms allocate limited resources, and how an individual resolves these trade-offs can greatly impact fitness. Telomeres (i.e. noncoding strands that protect DNA integrity) shorten in response to senescence and exposure to stressors, and therefore may allow us to predict how animals allocate these limited resources. Most prior work on this topic focuses on how stress influences telomere shortening, with few studies addressing whether an individual's existing telomere length can be used to predict future trade-off resolutions under challenging conditions. Here, we used wild female tree swallows *Tachycineta bicolor* to test the hypothesis that telomere length predicts how individuals resolve trade-offs among territory defense, parental care, and self-maintenance. We measured constitutive variation in telomere length and female aggressiveness, as well as maternal provisioning rates after treatment with either saline or lipopolysaccharide (LPS) injection, an immunological stressor that elicits an acute sickness response. Results indicate that the degree to which telomere length predicts trade-offs may depend on an individual's condition and the severity of the stressor. Furthermore, trade-offs between territory defense and parental care were only found in individuals with longer telomere lengths, a pattern that has implications for age- or stress-related variation in trade-off resolution and how it is shaped by natural selection. Collectively, our results link variation in telomere length with multiple components of vital life history trade-offs, suggesting that telomeres are not only reactive to stressors but they are also predictive of an individual's response to stressors.

62-4 SANDMEIER, FC*; WEITZMAN, CL; TRACY, CR; Colorado State University-Pueblo, University of Nevada, Reno; *franziska.sandmeier@csupueblo.edu*

Cooler thermal regimes and higher lymphocyte numbers are associated with lower levels of pathogen (Mycoplasma agassizii) in Mojave desert tortoise populations

We surveyed 22 populations of Mojave desert tortoises (*Gopherus agassizii*) across their range in the spring seasons of 2010-2012. In addition to testing for visible severity of respiratory disease, prevalence of the pathogen *Mycoplasma agassizii*, and infection intensity, we quantified bacteria-killing ability (BKA) of blood plasma and differential white blood cell numbers in the peripheral blood. Principal component analyses of these immunological measures indicated the variation was mostly explained by two PCs, PC1 representing inflammatory processes and PC2 representing specific responses not immediately associated with inflammation (largely driven by lymphocyte numbers). Climatic variables were calculated from NOAA weather stations and PRISM data. Model selection and Akaike criteria indices were used to evaluate which climatic and/or immunological variables may be important in affecting prevalence of *M. agassizii*, mean infection-intensity of M. agassizii, and visible disease among populations. Lymphocytes were strongly associated with decreased loads of *M. agassizii* and cooler thermal regimes. While clinical signs of disease were not associated with lymphocytes, they were associated with PC1, representing inflammatory processes. This study suggests that tortoises may use multiple immune functions to control *M. agassizii*, and that lymphocyte function may reduce pathogens without initiating the inflammatory processes that leads to observable disease. Because lymphocytes are known to have a phagocytic function in reptiles, the temperature-dependence of both antibody production and phagocytosis by these cells should be addressed in future experiments.

P1-31 SANG, S*; TIETJEN, K; COATES, MI; University of Chicago; *stephaniesang@uchicago.edu*

Getting a grip on claspers: a new description of chimaeroid cranial clasper anatomy

Male chondrichthyans bear a pair of pelvic claspers, but male chimaeras (*Hydrolagus colliei*) have five of these devices, including a pre-pelvic clasper on each half of the girdle, and a fifth clasper projecting from the forehead. Examples of such cranial claspers are present in all living and many fossil chimaeroids, at least as far back as the Mesozoic. Cranial clasper function is uncertain, but it appears likely that the structure is used for grasping the female during copulation (station holding?); to the best of our knowledge, this function and behaviour has not been properly documented. We suggest these claspers represent a classic evolutionary novelty, as well as an extra midline appendage unique to chimaeroids that has persisted throughout much of the phylogenetic history of the clade. However, these structures have received little scientific attention, and for this reason we investigated a cranial clasper from *Hydrolagus colliei* using micro-computed X-ray tomography and soft tissue thin sectioning and staining. Cranial claspers are already known to consist of a cartilage-supported shaft with a pad of denticles at the distal tip. Unexpectedly, we found that the denticles are strikingly tooth-like in terms of their individual morphology, and collectively in their patterned arrangement. Each denticle base underlies the base of its proximal neighbour, thus forming what appears to be a successive series. Taken together, these denticles resemble a tightly packed suite of tooth whorls, and we infer that these teeth developed in a coordinated, spatiotemporally restricted manner. This discovery prompts new consideration of cranial clasper biology, and whether these structures manifest a classic example of evolutionary developmental 'bricolage.'

123-1 SANGER, TJ*; LACHANCE, D; HARDING, L; KYRKOS, J; CZESNY, B; MATA, C; STROUD, JT; Loyola University Chicago, Senn High School, Florida International University; *tsanger@luc.edu*

The Mechanisms of Thermal Stress Induced Craniofacial Malformation in Lizards

Terrestrial ectothermic reptiles are under increasing risk of global warming. Embryonic life is particularly sensitive to thermal stress, although few studies have examined the tissue- and stage-specific effects of thermal stress in reptiles. We have examined the production of developmental malformations in the burgeoning embryological model system *Anolis sagrei*. Examination of field incubation conditions indicates that this species is developing on the cusp of its thermal limits during the peak summer months. We have discovered a narrow window around ovipositon that is sensitive to thermal stress and the concomitant induction of developmental malformations. Craniofacial malformations represent the most abundant class of malformation observed. These malformations range from a foreshortened or narrow face to embryos with complete loss of the neural crest derived facial skeleton. We have shown that these malformations are correlated with localized cell death in the developing forebrain during a narrow window of craniofacial patterning. Using a concentration gradient of a small inhibitors applied directly to the developing egg we have reproduced the craniofacial phenotypes observed in the thermally stressed embryos, verifying our candidate mechanism of induction. Our results raise greater concern over the potential for climate change to disrupt the reproduction and survival of terrestrial ectotherms.

P3-215 SANO, K*; OHNO, S; IZUHA, A; IMAI, K; KAWAGUCHI, M; YASUMASU, S; Josai University, Japan, Sophia University, Japan; *kaori-s@josai.ac.jp*

Neofunctionalization of duplicated hatching enzyme genes in the teleost evolution

Gene duplication is one of the driving forces of evolution. In the most cases, one of the duplicated genes is subsequently lost, but in some cases, the gene diverges and acquires a new function. The latter phenomenon is called neofunctionalization. At a time of hatching of teleost, the embryos secrete enzyme(s) to digest their egg envelopes. The enzymes are named hatching enzyme. In the evolution of teleost, the hatching was originally performed by a single type of hatching enzyme. The enzyme swells and softens egg envelope, and embryos ruptured the softened egg envelope by their movement. In the early stage of teleost evolution, the gene duplication and neofunctionalization has occurred. The euteleost fishes, the most diverged group of teleost, possess the duplicated two hatching enzymes genes, HCE (high choriolytic enzyme) and LCE (low choriolytic enzyme). HCE has kept the activity of ancestral enzyme, swelling the egg envelope, and LCE acquired new function, solubilization of the swollen egg envelope by cleaving two specific sites on egg envelope proteins. We are interested in the mechanism of neofunctionalization. In this study, we tried to identify the key amino acid residues for neofunctionalization of medaka Oryzias latipes HCE and LCE using mutant recombinant (rec.) hatching enzymes. As the result, the rec. HCE substituted 4 amino acid residues to LCE-type residues acquired the LCE-like cleavage activity, and lost the original HCE activity. Conversely, the rec. LCE with the 4 amino acid substitutions to HCE-type residues acquired the HCE-like cleavage activity, and lost the original LCE activity.

P2-185 SANSONE, AM*; MAYERL, CJ; BLOB, RW; Clemson University; *sansone@g.clemson.edu*

Tails as rudders in swimming turtles: performance implications of sexual dimorphism

Two important metrics of aquatic locomotor performance are hydrodynamic stability and the ability to execute turns. Stability can help reduce the energetic costs of steady swimming, and rapid execution of turns in a limited space can facilitate successful prey capture and escape from predators. In human-engineered aquatic vehicles, stability and turning performance can be improved via a rudder, which can be oriented parallel to the long axis of the vehicle to act as a stabilizing keel, or adjusted to redirect oncoming water flow, changing the balance of forces and turning the vehicle. Similar to human-engineered vehicles, turtles possess a rigid body and a posteriorly directed midline structure, the tail, which could be used like a rudder during swimming. However, in many turtles, tail length is sexually dimorphic, with males having significantly longer tails than females. We examined whether turtle tails might function similarly to the rudders of boats, and the implications of such use for swimming performance in males versus females, by comparing stability and maneuverability of male painted turtles (*Chrysemys picta*) under two conditions: normal swimming, and swimming after the tail had been secured inside the shell with tape (a proxy for the highly-shortened tails of females). In general, turtles were more stable in trials with full tail use, especially in positional displacements such as heave and sideslip. Also, whereas turning rate was not affected by tail use, full use of the tail allowed turtles to have a substantially smaller turning radius. Thus, much like boat rudders, turtle tails may facilitate the execution of tight turns. Moreover, this structural difference between male and female turtles might contribute to differences in their swimming performance.

117-7 SANTANA, SE*; ARBOUR, JH; CURTIS, AA; University of Washington; *ssantana@uw.edu*

Echolocation and Diet Shaped Cranial Evolution During the Ecological Diversification of Bats

The mammalian skull performs multiple functions, including feeding and protecting the brain and sensory organs. Dietary adaptation is considered a major driver of mammal skull diversity, but there have been few, large-scale quantitative tests of the impact of feeding versus other functions on skull morphological evolution. Bats are an ideal group to investigate this issue because they represent 20% of all mammals, are diverse in cranial morphology, and encompass nearly the full spectrum of mammal diets and sensory ecologies. We explore whether and how the macroevolution of skull shape is related to feeding strategies in bats, or if other functional demands have influenced their cranial diversity. We compiled a large dataset of 3D representations of bat skulls, spanning all major bat lineages, diets and sensory ecologies. We used this dataset in phylogenetic comparative analyses of skull shape to (1) map major evolutionary trends, (2) detect selective regime shifts without imposing a priori hypotheses, and (3) investigate the association among skull shape evolution, diet, and primary sensory modality across bats. We found that the bat skull morphospace is characterized by gradients in skull elongation, facial flexure, and zygomatic breadth. Old World fruit bats (Pteropodidae) tend to be morphologically distinct, as are lineages of specialized neotropical frugivores (Stenodermatini) and insectivores (Mormoopidae). The evolution of skull shape across bats is well explained by selective regimes that broadly match echolocation use and type. However, patterns of skull shape evolution mirror dietary evolution within the most trophically diverse bat lineage (Phyllostomidae). Altogether, these results illuminate how multiple functions have impacted skull evolution during the ecological and lineage diversification of bats.

129-3 SANTHANAKRISHNAN, A*; KASOJU, VT; SENTER, M; ARMEL, K; MILLER, LA; Oklahoma State University, Univ. of North Carolina, Chapel Hill, Univ. of North Carolina, Chapel Hill; *askrish@okstate.edu*

How Tiny Insects Get Far: Intermittent Parachuting with Bristled Wings

Free takeoff flight recordings of thrips (body length under 1 mm) show that they can intermittently cease flapping and float passively downwards by spreading their bristled wings. This type of drag-based parachuting can be advantageous in lowering the falling speed, and could potentially aid in long-distance dispersal by minimizing energetic demands needed for active flight. It is unclear whether bristled wings such as those observed in thrips can reduce drag generated in parachuting. In this study, we comparatively examine parachuting using bristled wings and solid (non-bristled) wings. Forewing angles in parachuting and settling velocities were obtained from free takeoff flight videos. A solid wing model and bristled wing model with bristle spacing to diameter ratio of 5 performing translational motion were comparatively examined using a dynamically scaled robotic model. We measured force generated under varying wing angle from 45-75 degrees across a Reynolds number (Re) range of 1 to 15. Drag experienced by the wings decreased in both wing models when varying Re from 1 to 15. Leakiness of flow through bristles, visualized using spanwise particle image velocimetry measurements, and implications for force generation will be presented.

103-8 SANTIBANEZ-LOPEZ, CE*; NOLAN, ED; SETTON, EVW; SHARMA, PP; Univ. Wisconsin-Madison; *santibanezlo@wisc.edu*

Gene expression in appendages of Centruroides sculpturatus clarify the evolutionary origin of the scorpion pectine

The versatility of the articulated appendages of arthropods has contributed to their evolutionary success, granting them expansion of their ecological niche space. While the genetic mechanisms controlling the patterning of appendages are well understood for arthropod models like *Drosophila melanogaster,* the genetic basis for the patterning of appendages unique to arachnids (e.g., book lungs, chelicerae) remains a mystery. Within Arachnida, scorpions are among the oldest lineages and are distinguished from other arachnid groups by a unique pair of wing-like organs called pectines, whose relationship to the walking leg is unclear. We utilized a developmental transcriptome of *Centruroides sculpturatus* to identify homologs of appendage patterning genes common to arthropods, such as *dachshund* (dac), *engrailed* (en) and *wingless* (wg). To elucidate the nature of the scorpion pectine and build upon understanding of its positional and genetic homologies to other appendages, we surveyed the expression of these genes in developing scorpion embryos. Based upon these data, we homologize walking legs with the inner ramus of the pectine, whereas our data suggest that the blade of the pectine represents an exopod derivative. The lack of distal expression of *Distal-less* and *aristal-less* suggests that their patterning is fundamentally different from telopodal appendages (e.g., pedipalps or legs).

P3-216 SANTIBANEZ-LOPEZ, CE*; KRIEBEL, R; BALLESTEROS, JA; SHARMA, PP; Univ. Wisconsin-Madison; *santibanezlo@wisc.edu*

Evolution of three-dimensional structure of the calcin family peptides in the scorpion venom

Calcins are small peptides that bind to ryanodine receptors, which have been isolated only from the venom of the non-Buthidae scorpions. The physical-chemical properties, along with structure-function relationships, of the calcins are known from a limited sample of seven species in five families. Here, we conduct bioinformatic surveys of putative calcins orthologues using all available scorpion venom transcriptomes, including a newly sequenced transcriptome of the species *Kololt magnus*. We provide a comprehensive analysis of the structure of 39 putative calcins (from 35 species in 14 families), based on their primary sequence and their 3D structure models, using a new scorpion phylogenomic framework and morphometric tools. The reconstructed phylogeny of the full precursor of calcins mirrors the phylogenetic tree of the scorpions. Purifying selection is detected in 24 sites of the mature peptide sequence, whereas three codons are evolving under positive selection. Our morphometric analyses of the frontal and lateral surfaces of the 3D structures suggest divergence between calcins and the ICK calcin-like peptides from the buthid scorpion venom. Additionally, only two calcins exhibit major evolutionary shifts (detected under an Ornstein-Uhlenbeck model) in their 3D structures, net charge, molecular weight and volume. Our results demonstrate that calcins are the first molecular synapomorphy of the parvorder Iurida.

18-1 SANTINI, F*; ZAPFE, K; FREDERICH, B; DORNBURG, A; Associazione Italiana per Studio Biodiversita', North Carolina State University, University of Liège, North Carolina Museum of Natural Sciences; *francesco.santini@alumni.utoronto.ca*

A macroevolutionary look at the history of herbivorous fishes in coral reefs

Herbivorous fishes play a key role in coral reef habitats, controlling the growth of algae on corals and thereby preventing negative cascading effects on both reef health and community-wide patterns of species diversity. Herbivory has evolved independently in several groups of coral reef fishes, including rabbitfishes (Siganidae) and surgeonfishes (Acanthuridae). Although both of these groups posses a rich fossil record that makes them ideal groups from which to study how the evolution of herbivory has impacted reef fish diversification dynamics, few studies have investigated these clades in detail. Combining molecular and morphological datasets that include both extant and fossil taxa into a total evidence approach, we provide a new timescale for the evolutionary history of these clades. Our results demonstrate much earlier origins of these groups than those indicated by the fossil record, supporting a substantial a radiation of herbivorous fishes that began in the Cretaceous, followed by episodes of significant extinction during the late Eocene and Oligocene. Integrating our timetree with morphometric data collected from over 1000 digitized images for both groups, we further investigate the tempo and mode of phenotypic evolution within these clades, and will discuss our findings.

P2-24 SANTOS, G-P.*; LEPORE, T.; Raymond M. Alf Museum of Paleontology; *gsantos@webb.org*

Accessible SciComm: Utilizing Technology to Create an Inclusive and Accessible Science Narrative

There has been a notable increase in the amount of technology within museums, exhibitions, and other educational institutions to enhance science communication and provide supplementary information. Yet modern science communication and exhibit design relies heavily on visual mediums and is catered toward "general" audiences - those without sensory impairment, those who are neurotypical, and/or those who speak English fluently. This broader design can inadvertently create a feeling of exclusion for groups outside the "general" audience; attempts to enhance inclusion through secondary engagement tools such as pamphlets or audio tours often risk members of these specialized audiences feeling removed from the overall experience. Additionally, the development and maintenance of such secondary engagement tools can be exclusive due to the high cost of maintenance and development for many museums and science communicators. At the Raymond M. Alf Museum of Paleontology, we are attempting to create a more inclusive museum experience and develop more accessible science communication media by combining principals of universal design with the application of cost-effective technology such as augmented reality, smartphone technology, and 3D printing. Augmented reality (AR) can be applied to existing exhibits to overlay language translations, play subtitled videos, or enable audio dictation. Combining AR audio dictation with 3D printed replicas can be used to develop tactile experiences for the visually impaired. Simplified graphic overlays and touchscreen tactile aids can even be developed to better present information to neuroatypical guests. The platforms we implement are free to low-cost and user-friendly for institutions lacking funding or expertise in inclusive design, and can be easily updated.

37-4 SARDELLA, B*; KING, M; California State University, Stanislaus; *bsardella@csustan.edu*

Ventilation Cessation Behavior of the Mozambique tilapia: A strategy for multi-stressor tolerance?

Mozambique tilapia (*Oreochromis mossambicus*) are incredibly stress tolerant with respect to environmental salinity, hypoxia, and ammonia concentrations. However, previous work has shown that they have difficulty with low temperature acclimation. We quantified the effects of acclimation temperature and salinity on the thermal tolerance of tilapia as assessed by Critical Thermal Maxima (CTMax) and Critical Thermal Minima (CTMin). During thermal challenges, we observed two unexpected behaviors; Ventilation Cessation Behavior (VCB) and Aquatic Surface Respiration (ASR), and we concluded that the use of these extended thermal scope in both freshwater (FW) and two-thirds seawater (SW). ASR has been previously observed in this and other species in response to oxygen poor water, but its use in response to thermal stress was unexpected. VCB was defined as the cessation of opercular movement for greater than 15 seconds and its observation was completely novel. Both behaviors limit the exposure of the gill epithelium to a waterborne stressor, but VCB likely has repercussions with respect to oxygen homeostasis. ASR was the more preferred behavior in CTMax trials, and VCB was preferred for CTMin, when oxygen demand was reduced. We hypothesize that this behavior potentially underlies the impressive stressor tolerance of this species. Previous work has shown that whole-animal oxygen consumption was inversely proportional to environmental salinity, and that ATPase activity was also reduced in liver and brain extracts under these conditions. The recent observation of VCB is a potential explanation for those findings. To investigate this further, we have monitored tilapia behaviors and oxygen consumption during a series of stressor exposures to determine which stressors elicit VCB (or ASR) and what the physiological consequences of this behavior may be.

4-5 SARGENT, JC*; CAMPBELL, JB; HARRISON, JF; ASU; *jcsargen@asu.edu*

Accumulation of Gut Bacteria May Cause the Age-Related Decline of Anoxia Tolerance in Adult Drosophila melanogaster

Cell death occurring from anoxia is the major pathology during heart attack, stroke and multiple other diseases. Humans vary substantially in their ability to survive anoxia, especially across ages, and the basis to this variation is not well-understood. *Drosophila melanogaster* have similar metabolic pathways to humans but have much better capacities to tolerate anoxia, suggesting that understanding mechanisms of anoxia tolerance in flies may provide insight for the development of new medical treatments. We exposed adult *Drosophila*, ages 1, 3, 5, 7, 9, and 12 days old, to six hours of anoxia and assessed survival 24-hours post-treatment. Seventy-nine percent of adults one day past eclosion survived; while only 10% of twelve-day-old adults survived; thus *Drosophila* show age-related decline in anoxia tolerance like humans. In anoxia, ATP levels declined rapidly (< 30 min) to near-zero levels in both 1 and 12 day old adults; thus the better anoxia-tolerance of young adults is not due to a better capacity to maintain cellular energetic status. The concentration of bacteria in the gut is known to increase strongly with age in *Drosophila*. To test whether declining anoxia tolerance might be due to this increasing bacterial load, we replaced their food daily, every third day, or every sixth day, allowing us to vary gut bacterial load from low to high, respectively. At 12 days of age, each treatment group was exposed to six hours of anoxia and assayed for gut bacterial load. Anoxia tolerance was strongly and negatively affected by bacterial load. These data suggest that increasing bacterial load may play an important role in the age-related decline of anoxia tolerance in *Drosophila*. This research was supported by NSF IOS 1256745 and the SOLUR program at ASU.

P2-67 SARGENT, BA; BOYDEN, HM; SMILEY, JT; ROBERTS, KT; RANK, NE; DAHLHOFF, EP*; Santa Clara University, White Mountain Research Center, Sonoma State University; *bsargent@scu.edu*

Effects of decadal climate change on population dynamics and metabolic physiology of a montane willow beetle

Climate change is expected to shift species distributions as populations grow in favorable habitats and decline in harsh ones. For montane animals, the ability to escape hot, dry conditions at low elevation may be limited by cold temperatures, variable snowpack, and low oxygen at high elevation. The willow beetle *Chrysomela aeneicollis* is restricted to high elevation habitats in the southernmost part of its range, California's Sierra Nevada. From 2008-2017, beetle abundance and distribution was measured along steep elevation gradients (2500-3600 m) at 45 sites in 7 creek drainages. Loggers deployed at each site captured annual variation in air temperature and snowpack. The elevation at which peak adult abundance occurs has shifted significantly upwards in the past decade; furthermore, abundance at these elevations has declined precipitously, particularly during a recent severe drought. Abundance was also inversely correlated with winter air temperature. To investigate physiological mechanisms driving distribution shifts, we measured metabolic rate (adults) and running speed (larvae, adults) at high elevation, before and after heat treatment, for beetles held at high or low elevation in the laboratory. Adults held at high elevation had higher metabolic rates and running speeds after heat treatment than those held at low elevation, and high-elevation larvae recovered running speed after treatment more effectively than their low elevation counterparts. These results suggest that continuing to "move up the mountain" to escape hot, dry conditions may be feasible via phenotypic plasticity in metabolism, but may result in reduced population size, increasing the risk of extinction as climate change proceeds.

P3-210 SARIKAYA, DP *; DAVIS, SL; TARAKJI, A; KOCHUMMEN, AA; KHAN, NY; SHEEHY, H; BEGUN, DJ; Univ. of California, Davis; *dpsarikaya@ucdavis.edu*

Metabolic traits and starvation response in Drosophila melanogaster clinal populations

Drosophila melanogaster populations have undergone adaptive evolution along the latitudinal clines of North America and Australia. The genetic analyses of the clinal populations often reveal signatures of adaptive evolution on metabolism-related genes, yet the metabolic characteristics of clinal populations is poorly understood. Laboratory studies of metabolism in *D. melanogaster* inbred lines suggest that reduced sugar and fat levels are likely to correlate with decreased starvation resistance. To better understand metabolic traits and how they may influence survival in natural populations, we measured adult stored triglyceride and glucose levels, larval starvation response, and adult starvation response in 10 lines each from high and low latitude populations at 21 and 25C. We measured wing size in starved and well-fed rearing conditions, and found that while the high latitude populations were larger than the low latitude population when well-fed, there were no significant differences in wing size when starved, suggesting that both populations reached a similar threshold for starvation response. We measured whole body triglyceride and glucose levels using enzymatic assays on flies maintained at 25C and found overall higher levels of triglyceride and glucose in the high latitude populations, albeit non-significant. Further results and correlation between metabolic traits and starvation response at 21 and 25C will be presented.

42-7 SASSON, D/A*; JOCSON, D; FOWLER-FINN, K; University of Saint Louis , University of Saint Louis; *daniel.sasson@slu.edu*

The effects of temperature on reproductive communication in the treehopper, Enchenopa binotata

Climate change threatens to affect almost all aspects of animal ecology, physiology, and behavior, and poses particular challenges to organisms unable to migrate to areas conforming to historical temperature ranges. We focus on an understudied aspect of climate change - the impact of rising temperatures on reproductive communication. The treehopper *Enchenopa binotata* (Hemiptera: Membracidae) uses vibrational signals that travel through plant stems to coordinate mating. Males produce advertisement signals and females respond to attractive signals to form a duet that facilitates pair formation. Females select mates based on signal frequency (Hz), but signal frequency is sensitive to temperature. We measured individual and family-level variation in signals and preferences across a range of biologically-relevant temperatures (18 - 36C) to test whether changes in temperature lead to breakdowns in communication, which may occur if the male signal frequency, but not female preference, varies with temperature. We used a full-sib, split-brood quantitative genetics breeding design which allowed us to test for population, family, and individual-level variation in male signaling and female response behavior. We found a slight mismatch in the overall populations for the temperature at which males and females were maximally active, with females responding most at 30C and males signaling most at 27C, which may generate a mismatch in reproductive activity level. We also found an overall increase in the frequency of male signals and female peak preference at higher temperatures and significant individual and family-level variation in these traits. Our results suggest that patterns of mating in a population may depend on an interaction between the genetic backgrounds of interacting individuals and ambient temperature.

96-1 SATTERLIE, RA; University of North Carolina Wilmington; *satterlier@uncw.edu*

Steering Function of the Tail in the Pteropod Mollusc Clione limacina

The primary mechanisms for steering during slow and fast swimming in the Pteropod mollusc *Clione limacina* include flattening and bending of the tail. The tail musculature includes well-develop longitudinal muscle bands, circular muscle, and dorso-ventral muscles. Since the muscles are associated with a central hemocoelic cavity, the longitudinal bands produce bending, while the dorso-ventral muscles flatten the tail. The circular muscle serves to increase tail length. All three contribute to the increase in fluid pressure that occurs during the change from slow swimming to fast swimming. Serotonin innervation of the tail musculature, primarily by two symmetrical pairs of neurons in the pedal ganglion, suggest peripheral modulation of the tail musculature during fast swimming.

P1-1 SATTERLIE, RA*; YOPAK, K; University of North Carolina Wilmington; *satterlier@uncw.edu*

Design-A-Nervous System

We have developed a capstone assignment for our BIO 443 Neurobiology class that gives students an opportunity to apply the information discussed in class in a creative, intuitive way. Volunteer groups present their project to the class for discussion and critique prior to the submission date. The assignment: Design an organism that has a nervous system comprised of only 12 neurons. The organism has to be able to survive in its environment, so it must be able to move toward food (must be capable of locomotory activity - it can not be sessile), obtain food, and move away from danger and/or defend itself. Sensory cells count as neurons, but obviously, muscles do not. Provide a complete "wiring diagram" of the brain and include a list of neurons and their special properties. In addition to neurons, you will have to describe musculature as well, but you do not have to pay attention to numbers of muscle cells. In addition to the organism, you must describe the environment in which it lives, and give a brief description of the organism (you can even give it a name). Your organism does not have to be like any known living form, and your design can be fairly outrageous, as long as it is functional. Also, you can not defy the laws of physics and chemistry. More importantly, you can not describe neurons that have properties outside of those that are currently known.

P3-262 SAUER, AR*; ESPOSITO, L; San Jose State University, California Academy of Sciences ; *ashleysauer1@gmail.com*

Communicating Science: Creating a Field Guide of the Vizcaino Biosphere Reserve for Community Outreach

Community outreach and science communication can have large and lasting impacts in regions where science education infrastructure is not well supported. Efforts to increase levels of science education are important for sustaining the health and longevity of biodiverse regions and can provide tools for the public to make informed decisions about the health and future of their unique natural environment. My project focuses on the ongoing outreach in the Vizcaino Biosphere Reserve in Baja, California. "Islands & Seas", a non-profit organization co-founded by Dr. Lauren Esposito, works to create research facilities that serve as centers for science and environmental education. In the areas where this team conducts research, Islands & Seas brings outreach to local schools to help inform and advise future generations about preserving their regional diversity and resources. As a scientific illustrator, I have produced illustrations that visually communicate the biodiversity research and conservation efforts made by Dr. Esposito and her collaborators. The culmination of my work will result in an informational field guide of the Vizcaino Biosphere Reserve to represent the biodiversity of this region and communicate that knowledge to local communities, educating them about myths and misconceptions associated with commonly encountered organisms. Islands & Seas will distribute this field guide during its annual community outreach events in the region. Our field guide will include informational text about each organism in Spanish to ensure accessibility to the local schools and communities. The objective of this field guide is not only to inform and educate, but to generate interest and participation in conservation for the communities of Baja, California.

2-3 SAULSBURY, J.*; MESSING, C.G.; BAUMILLER, T.K.; University of Michigan, Ann Arbor, Nova Southeastern University Oceanographic Center; *jgsauls@umich.edu*

Coelomic Skeletal Structures in Fossil and Recent Featherstars (Comatulida, Crinoidea): Diversity, Function, and Taxonomic Implications

Featherstars - those crinoids that discard the postlarval stalk - constitute the majority of extant crinoid species and are prominent members of many coral reef and deep-sea assemblages. However, our understanding of relationships within the group remains hampered by rampant homoplasy and high intra-specific variability. Several recent molecular phylogenies have resolved some uncertainties but have suggested many clades without known synapomorphies. Although external morphology for this group is relatively well-documented, internal morphology is underexplored, in part due to the difficulty of applying traditional histological methods to crinoids. Here we present preliminary data from a survey of the internal anatomy of modern and fossil featherstars based on X-ray micro-computed tomography (µCT) and scanning electron microscopy. Emphasis is placed on the structure of the somatocoel (one of three paired coeloms in echinoderms) within the calyx. The crinoid skeleton, including the central plug and basal rosette, conforms closely to the shape of the somatocoel, allowing this structure to be preserved in fossil featherstars. The morphology of the somatocoel within the calyx is complex and relatively conserved within some families, making it a valuable new tool for classification. Potential synapomorphies for groups above the family level are discussed. The calyceal somatocoel is continuous with that in the arms and pinnules, and probably plays an important role in the crinoid circulatory system. µCT-based investigation of the internal anatomy of fossil featherstars may clarify uncertain taxonomic placements and allow the physiology of extinct taxa to be inferred.

34-2 SAVOIE, WC*; LI, S; WARKENTIN, RJ; GOLDMAN, DI; Georgia Tech; *wsavoie@gatech.edu*

Phototaxing Supersmarticle: a Locomoting Robot Made of Robots

Metazoans are composed of hierarchically organized living systems (cells). These populations form subunits (tissues and organs) which work together to accomplish tasks which the individual subunits cannot. To discover principles by which simple robots can be integrated to form more complex robots, we developed a stochastic locomotor composed of simple non-motile robots. We refer to the subunits as smart-active particles, or "smarticles". Smarticles (14 cm long) are 3D printed, three-link two degree of freedom robots with simple sensory capabilities (sound, light). The outer link positions are controlled by servo motors and can perform gaits (periodic closed trajectories in the 2D configuration space) or hold a configuration. Each smarticle is incapable of individually displacing or rotating. However, when confined inside an unanchored 20 cm plastic ring, smarticle ensemble (which we refer to as a "supersmarticle"), can displace through collisions among active smarticles and the ring. When all smarticles are active (performing gaits) the supersmarticle randomly diffuses with no favored direction. By introducing sensory capabilities -- a photoresistor to detect light levels and reactive behaviors based on the sensing -- the supersmarticle can achieve directed motion: when a smarticle detects light it stops its gait and holds in a straight position. This asymmetry generates stochastic but directed motion either towards or away from the inactive smarticle with an average drift speed of ~1 cm/s. The ring to inactive smarticle mass ratio determines the motion direction. A 1D simulation of the supersmarticle, which represents the active smarticles as a fluctuating mass, predicts the supersmarticle's movement in the frame of the inactive particle.

S2-10 SAWICKI, Gregory S.*; SPONBERG, Simon ; Georgia Tech; *gregory.sawicki@me.gatech.edu*

Perturbing the classical muscle work loop paradigm to unravel the neuromechanics of unsteady locomotion

Locomotion emerges from the interaction between the neuromechanics of muscle, compliant skeletal and connective tissues, and the physics of the environment. Classical workloop studies that coupled prescribed, steady-state strain cycles with phasic stimulation and measured net work/cycle revealed that a muscle can adopt diverse functions depending on the context in which it is activated (e.g., motor vs. brake). Perturbations away from steady-state yield transient but extreme demands on both muscle structure and function and offer a unique window for probing time-dependent factors driving force production that cannot not be captured by the FL/FV relations (e.g., short range stiffness). In this talk, we highlight two novel, in situ approaches that aim to extend the classical work loop paradigm in order to more closely approximate 'real world' locomotion on the benchtop. (1) Top-down: We can first identify salient, unsteady strain and stimulation parameters by recording limb kinematics and muscle activations from freely-moving animals during perturbed behaviors. Then, we can re-play these pre-recorded dynamics back onto that same muscle in isolation driving an intact limb/joint on the benchtop, enabling a systematic exploration of activation timings and or limb/joint trajectories in the vicinity of the 'real-world' baseline. (Sponberg) (2) Bottom-up: Alternatively, we can use feedback-controlled robotic tools to emulate the physics of the body/limb and environment on the benchtop, enabling muscle virtual reality experiments - that is, workloops where real muscles interact with artificially rendered loads. (Sawicki). Perturbing the classical muscle work loop paradigm should yield new insights into the dynamic processes and functional limits of muscle that are not exposed during steady conditions.

61-1 SCALES, J.A.*; BLOOM, S.V.; DEBAN, S.M.; CSU, Stanislaus, Univ. of South Florida; *jscales1@csustan.edu*

Correlated morphological evolution of ballistic tongue projection in plethodontid salamanders

Tongue projection in plethodontid salamanders ranges from relatively low performance, muscle-powered projection to extremely high performance, elastically powered, ballistic tongue projection. During ballistic projection, the tongue skeleton completely leaves the mouth and can achieve accelerations over 600 G. This impressive performance increase is largely accomplished via shifts in morphology as opposed to significant changes in muscle activation or physiology. For example, species exhibiting ballistic tongue projection tend to have increased collagen present in projector muscle compared to species exhibiting muscle-powered projection. However, tongue projection is a complex movement which involves both a tongue skeleton and projector muscles. Thus, we may expect that shifts in multiple morphological traits are required to produce the observed improvement in projection performance. To better understand the morphological underpinnings of ballistic tongue projection, we closely examine the evolution of both tongue skeleton and muscle morphology within Plethodontid salamanders. We find that several functionally important morphological traits show correlated evolution. For example, a lack of muscle fiber attachment to the tongue skeleton is correlated with a more circular epibranchial cross section. This correlated evolution of several traits has resulted in a suite of characters that clearly distinguish species exhibiting ballistic tongue projection from those using muscle powered projection.

91-2 SCALF, CS*; ASHLEY, NT; Western Kentucky Univ, Bowling Green, KY; *cassandra.scalf473@topper.wku.edu*

Transcriptomic Response to Immune Challenge in Zebra Finch (Taeniopygia guttata) using RNA-seq

Despite the convergence of rapid technological advances in genomics and the maturing field of ecoimmunology, our understanding of the genes that regulate immunity in wild populations is still nascent. Previous work to assess immune function has relied upon relatively crude measures of immunocompetence. However, with next-generation RNA-sequencing, it is now possible to create a profile of gene expression in response to an immune challenge. In this study, captive zebra finch (*Taeniopygia guttata*; adult males) were challenged with bacterial lipopolysaccharide (2 mg/Kg BW; dissolved in 0.9% saline) or vehicle (0.9% saline) to stimulate the immune system. Two h after injection, birds were euthanized and hypothalami, spleen, and red blood cells (RBCs) were collected. Taking advantage of the fully sequenced genome of zebra finch, total RNA was isolated, sequenced, and partially annotated in these tissue/cells. The data show 249 significantly upregulated transcripts in the hypothalamus, as well as 267 and 86 in the spleen and RBCs, respectively, relative to controls. Also, 91 transcripts in the hypothalamus, 421 in the spleen, and 26 in the RBCs were significantly down-regulated. More specifically, a number of immunity-related transcripts (e.g., IL1B, RSAD2, SOCS1) were upregulated among tissues/cells. Additionally, some transcripts involved in the reproductive process (ESR1, NR5A1, ZP4) were down-regulated, suggesting a potential trade-off in expression of genes that regulate immunity and reproduction. Unlike mammals, birds have nucleated RBCs, and these results suggest a novel transcriptomic response of RBCs to immune challenge. Lastly, molecular biomarkers could be developed to rapidly screen bird populations by simple blood sampling in the field.

P1-32 SCANTLEBURY, S/S; KLOHMANN, C/A; PAKZAD, I/Y; SCOTT-BüCHLER, C; VOMPE, A/D; FIORENZA, E/A*; FARINA, S/C; SCANTLEBURY, Samarr; Cornell University, Ithaca, University of Washington, Seattle, Harvard University, Cambridge; *samarrascantlebury@gmail.com*

Linking gill raker morphology to diet in suction-feeding sculpins (Cottoidea)

Gill rakers of ray-finned fishes are bony structures that extend anteriorly off the gill arches into the buccopharyngeal cavity. Filter-feeding fishes have highly elongate and filamentous rakers to filter plankton during ram and suspension feeding. However, many ray-finned fishes that do not filter feed still retain small and widely spaced rakers that are assumed to play a role in protecting gill tissue during feeding. To understand how the morphology of non-filtration rakers evolves in response to diet, we studied a group of closely related fishes, the sculpins (superfamily Cottoidea). Sculpins have a wide range of diets, although they are all primarily suction feeders. We examined 12 sculpin species from the Pacific Northwest using scanning electron microscopy to take measurements of rakers. We quantified evolutionary correlations of raker morphometrics, head measurements, and previously published diet data using phylogenetically independent contrasts and phylogenetically corrected ANOVAs. We found that premaxillary length, raker diameter, and raker spacing were larger in species that primarily ate prey that required manipulation. This is one of the first studies to directly correlate raker size to diet in non-filter-feeding fishes, and the relationship between raker diameter and prey type implies that wider rakers are used to protect the gill tissue during prey manipulation.

120-7 SCHACHAT, SR; Stanford University;
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Phanerozoic pO_2 and the early evolution of terrestrial animals
Concurrent gaps in the Late Devonian/Mississippian fossil records of insects and tetrapods (i.e., Romer's Gap) have been attributed to physiological suppression by low atmospheric pO_2. Here, updated stable isotope inputs inform a reconstruction of Phanerozoic oxygen levels that contradicts the low oxygen hypothesis (and contradicts the purported role of oxygen in the evolution of gigantic insects during the late Paleozoic), but reconciles isotope-based calculations with other proxies, like charcoal. Furthermore, statistical analysis demonstrates that the gap between the first Devonian insect and earliest diverse insect assemblages of the Bashkirian Stage requires no special explanation if insects were neither diverse nor abundant prior to the evolution of wings. Rather than tracking physiological constraint, the fossil record may accurately record the transformative evolutionary impact of insect flight.

P3-232 SCHAPER, EG*; MORINAGA, G; SILER, CD; BERGMANN, PJ; Clark University , Oklahoma University ;
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Microspatial Niche Partitioning in Semi-fossorial Lizards (Sincidae:Brachymeles)
Analyzing microhabitats can provide insights into ecomorphology, as well as community structure and assembly. The Southeast Asian skink genus, *Bracyhmeles* is semi-fossorial, yet little is known about its species' ecologies. Species of *Bracyhmeles* range in form from long, slender, and completely limbless, to robust, limbed, and pentadactyl in form. In addition, several species exhibit intermediate morphologies including reduced limbs with zero to five digits. Phylogenetic analyses support evidence for complete limb loss and multiple instances of digit loss and re-acquisition. We sought to test whether limb and digit loss and re-acquisition was related to microhabitat use. Microhabitat variables included soil moisture, pH, density, and particle size composition. In addition, canopy cover data, ground cover data, and habitat characteristics such as proximity and size of trees and shrubs were collected. Ten species were analyzed: four fully limbed, five with reduced limbs and digits, and one that was completely limbless. We expected differences in microhabitat selection with more robust and pentadactyl species occupying soils of greater particle size and density in spaces with more ground cover. We expected that species with reduced limbs and digits would inhabit soils with finer particle size and lower density, as well as less ground cover. Overall, we discovered species with differing morphologies did not partition their microhabitat. We hypothesize that resource partitioning may be occurring in other aspects of the niche such as diet. Robust, pentadactyl species may be eating larger prey than diminutive species, indicating that Brachymeles communities assemble with respect to trophic structure.

34-4 SCHIEBEL, PS*; RIESER, JM; HUBBARD, AM; CHEN, L; GOLDMAN, DI; Georgia Institute of Technology;
perrin.schiebel@gatech.edu
Collisional diffraction illuminates the neuromechanical control of snake sand-slithering
Snakes can coordinate the interaction of their flexible trunks with environmental heterogeneities to generate propulsion. The complicated relationship between shape and terrain in generalist snakes impedes deduction of neuromechanical controllers. The desert snake *C. occipitalis* uses a stereotyped travelling wave of body bending. We hypothesized this animal controls for its shape by targeting a pattern of muscle activation beneficial for movement on homogeneous granular matter (GM) [Schiebel et al SICB 2016]. Inspired by previous research probing the neuromechanics of organisms via environmental manipulations, we test the hypothesis by challenging *C. occipitalis* (N=9, 181 trials) to traverse a model desert terrain—a homogeneous sand-analogue substrate and a single row of posts perpendicular to the direction of travel. Visual feedback was eliminated by covering spectacle scales. After collision, trajectories were re-oriented into preferred directions of either ~0° (continuing straight) or ±21±9°. Since the shape changes of the snake were small during interaction, we posited that the collisional diffraction pattern resulted from a motor program that was largely preserved upon contact. We developed a model whose wave shape was similar to that used by the snake on GM and would passively deform upon interaction with obstacles. Following insights by Astley et al [SICB 2016] based on muscle activation patterns observed by Jayne [1988], we assumed external forces on the body were resisted only where active muscles would be lengthened; thus posts were accommodated by changing curvature so that active muscles would shorten further. The model captured the pattern of preferred trajectories, supporting our hypothesis that the specialist snake uses a motor program that is well-adapted for travel on GM and largely ignores interactions with sparse obstacles.

S8-3 SCHLOSSER, Gerhard; National University of Ireland Galway;
gerhard.schlosser@nuigalway.ie
Sensational innovations - The evolution of cranial sense organs in vertebrates
Evolving from filter feeding chordate ancestors, vertebrates adopted a more active life style. These ecological and behavioral changes went along with an elaboration of the vertebrate head including novel paired sense organs which develop from novel embryonic tissues, the cranial placodes. To understand how the new cranial sense organs of vertebrates evolved, we thus need to elucidate how their embryonic precursors, the cranial placodes emerged in evolution. Interestingly, many of the genes encoding signalling molecules or transcription factors, which govern placode development are evolutionary ancient and also play important roles for spatial patterning or neuronal or sensory differentiation in invertebrates. Furthermore, cell types that are homologous to placodally derived cells in vertebrates (e.g. the hair cells of inner ear and lateral line) have been described not only in other deuterostomes but also in more distantly related invertebrate taxa. Nevertheless, proper placodes - specialized ectodermal domains with a rapidly expanding population of multipotent sensorineural progenitors giving rise to high density arrays of neurons and receptor cells - evolved as new structures only in the vertebrate lineage. This suggests that the evolutionary origin of placodes involved recruitment of pre-existing cell types into new sense organs, due to changes in the connectivity between evolutionarily ancient regulatory genes - i.e. the rewiring of gene regulatory networks (GRN). In a recent RNA-Seq screen in Xenopus, we have begun to identify direct target genes of the transcription factor Six1 and its cofactor Eya1 - key regulators of placode development in vertebrates providing us with first insights into the GRN underlying vertebrate placode formation. Comparisons with other chordates and beyond are now required to reconstruct how this GRN was established by evolutionary rewiring of more ancestral GRNs.

P1-185 SCHLUSSEL, A*; LEININGER, EC; St. Mary's College of Maryland, St. Mary's College of Maryland, New College of Florida; *aschlussel@smcm.edu*

Mixture Effects of Neonicotinoid Insecticides and Selective Serotonin Reuptake Inhibitors on Daphnia magna

Water pollution caused by increasing pharmaceutical and pesticide use has the potential to negatively affect aquatic ecosystems through the effects of both individual chemicals and potentially synergistic mixtures. However, mixtures' synergistic effects are less well understood than the individual effects of their constituents. One mechanism for synergism is enzyme inhibition. The antidepressant fluoxetine inhibits cytochrome P450 enzymes (CYPs) in several taxa, including humans, fish, and polychaetes. CYPs are also used by macroinvertebrates to detoxify neonicotinoid insecticides, which can have detrimental impacts on aquatic macroinvertebrate communities. We hypothesized that fluoxetine inhibits invertebrates' ability to detoxify neonicotinoids, resulting in synergistic toxicity to aquatic macroinvertebrates. We performed acute (24-hour) immobilization assays on the water flea *Daphnia magna* to assess the toxicity of fluoxetine, the neonicotinoid imidacloprid, and a mixture of the two. Individual dose-response curves revealed an EC_{50} of 5.43 mg/L for fluoxetine and 10 mg/L for imidacloprid. A fluoxetine/imidacloprid mixture immobilized significantly fewer *D. magna* than did the individual chemicals, suggesting that these chemicals may interact antagonistically in *D. magna*. However, mixtures of imidacloprid and prochloraz, a known inhibitor of *D. magna* CYPs, also exhibited a near-significant antagonistic interaction. These antagonisms could stem from imidacloprid's inhibition of feeding in *D. magna*. Even if fluoxetine and imidacloprid are not synergistically toxic, they could still individually impact macroinvertebrates. Moreover, diversity in the invertebrate community suggests that research in additional species is warranted.

90-2 SCHMIDT, C*; KINNUNEN, R; GARROWAY, CJ; University of Manitoba; *schmid46@myumanitoba.ca*

Effects of Urbanization on Genetic Variation: Implications for Adaptability in Response to Rapid Environmental Change

Evolutionary responses to rapid environmental change likely require standing genetic variation. However, rapid environmental changes often fragment and reduce population sizes, thereby reducing genetic variation. Urbanization is an example of extensive, rapid environmental change, and thus provides a workable system to synthetically explore the extent to which environmental change tends to reduce genetic variation. There is evidence for both negative and neutral effects of urbanization on genetic diversity within populations. However, the extent to which genetic diversity loss due to environmental change can be considered general is unknown. Here, using publicly archived population genetic data sets from multiple species and localities, we assess how genetic diversity varies with human population density, a proxy for urbanization. We queried data repositories on DataONE for the >1300 mammal and bird species native to North America, which returned microsatellite data for approximately 60 species. From these data we will calculate population level inbreeding coefficients and gene diversities as measures of genetic variation. In so doing, we explore the effects of rapid environmental change on wildlife adaptability. The extent to which genetic variation is reduced by urbanization has important evolutionary implications for understanding evolutionary responses to rapid global change.

P2-25 SCHMIDT, C*; HESSENBERGER, DSI; University of Manitoba, Frontiers Media S.A.; *schmid46@myumanitoba.ca*

Getting Creative with Science Storytelling and Social Media

Science communication and outreach are becoming integral components of the modern scientist's toolkit. Social media platforms now provide researchers with the means to disseminate their work to broader audiences. Maintaining a steady, ongoing research narrative through social media is an excellent way to develop community connections, given its prevalence and easy accessibility. Social media platforms, however, are not interchangeable: they require different types of content, and cater to different audiences. This disparity is fertile ground to develop new ways of communicating science which draws from different disciplines within the arts and humanities. We recently hosted an online discussion focusing on social media and interdisciplinary modes of science communication via the @IAmScicomm Twitter account, which has >11,000 followers and is curated by different science communicators every week. Presented here are conclusions from this discussion, including takeaway points for all science communicators. Notably, a recurring theme was one of flexibility. To appeal to broader audiences, approaches which mix-and-match artistic media with various social media platforms have the most potential to generate interest. We briefly highlight pros and cons offered by different social platforms for science communication, and provide insights as to the benefits of using a group platform to increase the reach of science communication projects. We will also discuss the importance of showcasing the people behind research when telling a science story. Making use of the many resources available will enable scientists to share their work with their community in new, fun and engaging ways.

108-3 SCHMILL, MP*; CADNEY, MD; HIRAMATSU, L; ALBUQUERQUE, RL; LOUIS, MP; CASTRO, A; THOMPSON, Z; KAY, JC; BUENAVENTURA, D; RAMIREZ, J; GARLAND, JR, T; Univ. of California, Riverside; *mschm002@ucr.edu*

Conditioned Place Preference of Mice Selectively Bred for High Voluntary Wheel Running

Running acts as a natural reward and shares features with other rewarding behaviors, such as eating or taking drugs of abuse. Although exercise can attenuate withdrawal symptoms of chemical addiction, exercise itself is proposed to have addictive properties, as humans and rodents have shown signs of anxiety and depression after being denied exercise. Conditioned place preference (CPP) is a neuro-behavioral test of reward and reinforcement, widely used in studies of addictive processes in rodents. In typical protocols, individuals receive a reward (e.g., cocaine injection) paired with a specific environment (usually different floor textures) several times and are then tested for preference of the conditioned environment. We studied CPP in a unique exercise model of 4 replicate lines of mice selectively bred for high voluntary wheel running (HR) and 4 non-selected control (C) lines. HR mice run 3-times as much as C mice, in part based on evolutionary changes in their reward and motivational systems. We hypothesized that HR mice would differ from C in the extent to which they show a CPP following conditioning with rewarding drugs and/or wheel running. In experiment 1, HR and C mice were tested for CPP with cocaine as the reward. Both HR and C mice were significantly conditioned by cocaine, with no statistical difference between groups in the degree of conditioning. In experiment 2, mice were tested for CPP with wheel access as the reward. Specifically, mice were granted or not granted wheel access for 10 days, and each day removed from wheels or standard cages during peak wheel running and placed in CPP chambers for 30 min. Preliminary results show no significant conditioning by either HR or C mice. An upcoming third experiment will use Ritalin as the reward, a drug that has been shown to decrease wheel running of HR mice while increasing running by C mice.

26-1 SCHMITZ, L*; HIGHAM, TE; Claremont McKenna, Scripps, and Pitzer Colleges, UC Riverside; *ecomorph@gmail.com*

Adaptive Landscape of Eye Size Evolution in Geckos

Visually guided organisms depend on their ability to collect information about their environment in order to capture prey, avoid predation, and find mates. Visual performance therefore represents a proxy of whole-organism fitness. Physiological optics predicts that large eyes improve both acuity and sensitivity, and in particular night-active (nocturnal) species are considered to benefit from large eyes. However, large eyes come with extra metabolic cost, hence there is a potential trade-off between the benefits to visual performance and the cost attached to it. To better understand the evolutionary drivers of eye size, we turned to geckos (Gekkota), a diverse squamate clade with many night-active (nocturnal) species. Geckos are unusual in that they feature at least 19 evolutionary transitions between different diel activity patterns, offering the opportunity to evaluate the effects of changes in the photic environment on eye size. We collected species average data for 90 gekkotans and used time-calibrated molecular phylogenies to model eye size evolution. Phylogenetic generalized least squares models show that diurnal species have smaller eye diameters for given snout-vent length compared to other geckos, validating earlier non-phylogenetic comparisons. Quantitative analyses of residual eye size evolution in a Bayesian framework confirmed these initial results and added important new information. Selective regimes shifts towards smaller residual eye size are strongly supported for the major, but not all transitions to diurnality. We also found strong support for a regime shift towards larger eyes not linked with a change in activity pattern, but rather with a change of habitat to semi-arid, open habitats with unobstructed view of the surroundings. Our results suggest that diel activity pattern and habitat interact to control eye size evolution in geckos.

8-3 SCHNITZLER, CE; NGUYEN, AD; KOREN, S; GORNIK, SD; PLICKERT, G; BUSS, L; PHILLIPPY, A; MULLIKIN, JC; CARTWRIGHT, P; NICOTRA, ML; FRANK, U; BAXEVANIS, AD*; U. Florida, NHGRI/NIH, NUI-Galway, U. Cologne, Yale U., U. Kansas, U. Pittsburgh; *andy@mail.nih.gov*

The Genomics of Hydractinia: Understanding Regeneration, Allorecognition, and Stem Cell Biology

The cnidarians - organisms unified in a single phylum based on their use of cnidocytes to capture prey and for defense from predators - occupy a key phylogenetic position as the sister group to the bilaterians. Given their experimental tractability and great potential as emerging models for the study of regeneration, stem cell biology, and allorecognition, we are sequencing and annotating the genomes of two cnidarian species: *Hydractinia echinata* and *Hydractinia symbiolongicarpus*. What makes *Hydractinia* particularly attractive for study is that they possess a specific type of interstitial cell (or *i-cell*) that is pluripotent, expressing genes whose bilaterian homologs are known to be involved in stem cell biology. *Hydractinia* is also colonial, with a complex allorecognition system that lends itself to the study of host-graft rejection. Using PacBio, Illumina, and Dovetail-based strategies, high-coverage sequencing data indicate an estimated genome size of 774 Mb for *H. echinata* (84x coverage) and 514 Mb for *H. symbiolongicarpus* (94x coverage); these genomes are AT-rich (65%) and highly repetitive (47-51%). The vast majority of a set of evolutionarily conserved single-copy orthologs can be easily identified in these assemblies, and analyses of these whole-genome sequencing data have already provided important insights into the evolution of chromatin compaction, the mechanisms underlying allorecognition, and metazoan neurogenesis, while also establishing a strong foundation for future genomic and functional studies aimed at identifying new targets for therapies in regenerative medicine.

S3-11 SCHOENEMANN, B.; University of Cologne; *B.Schoenemann@uni-koeln.de*

Evolution of eye reduction and loss in fossil arthropods

The fossil record of arthropod compound eyes shows different modes and processes of eye reduction, sometimes leading to the loss of the eyes altogether. The first reason for having small, reduced eyes is to be a tiny organism with simply not enough space for establishing a regular compound eye. We find such a miniaturised system in the first planktonic trilobite so far known *Ctenopyge ceciliae* (Clarkson & Ahlberg, 2002) [trilobites: extinct arthropods, dominant during the Palaeozoic]. A reduction of compound eyes, or parts thereof, also occurs, if selective pressure for a high specialisation of eyes makes several facets fuse into a single functional unit. This possibly can be found in phacopid trilobites, ~400 million years old. Opaque conditions are often coupled with major extinction events during the Earth history, as in the late Permian, when more than 90% of all species died out. At other times, especially in many trilobites during the late Devonian, the reduction of eyes, often leading to total eye loss, has been documented in great detail, but in the same way it is intriguing to consider that certain coeval forms remained with good, unreduced compound eyes. In some trilobites eyeloss was compensated by the development of "compound noses". For different reasons the fossil record presents only very limited evidence about parasites, in which the eyes are often reduced or absent. Possibly a few blind Agnostids, distant relatives of trilobites during the Lower Palaeozoic, may have been parasitic, and there are blind fleas preserved in amber, which have not changed very much since the Mesozoic era. Pentastomids (Crustacea), worm-like parasitic organisms, already present in the Cambrian (~487Ma), have eyeless from the very beginning. Finally, blind deep-sea organisms are documented by the fossil record.

S6-7 SCHOENLE, LA*; ZIMMER, C; MILLER, ET; VITOUSEK, MN; University of South Florida, Hamilton College, Cornell University; *laura.schoenle@gmail.com*

Is variation in glucocorticoid regulation associated with fitness? A phylogenetic meta-analysis.

Glucocorticoid hormones, often called "stress hormones," mediate rapid physiological and behavioral changes that enable individuals to cope with the challenges of a fluctuating environment. Because glucocorticoids mediate the phenotypic response to immediate challenges, individual variation in the magnitude of the acute glucocorticoid stress response is often predicted to be positively associated with fitness. In contrast, individuals with higher baseline glucocorticoid concentrations are often assumed to be experiencing chronic stressors or to be less able to cope with challenges, and thus have reduced health or fitness prospects. However, these basic predictions neglect other important roles of glucocorticoids that may generate opposing hormone-fitness patterns. For example, elevations in baseline glucocorticoids are increasingly recognized to support energy acquisition during energetically demanding periods, and mounting a strong stress response may be particularly costly during some life history stages. Previous studies and reviews have found variable results; the presence and direction of glucocorticoid-fitness relationships often differ across species, sexes, and life history stages, but few clear patterns have emerged. Here, we present the first phylogenetic meta-analysis testing the relationship between glucocorticoids (baseline and stress-induced) and components of fitness (survival and reproductive success) across vertebrates. We compare this relationship across life history stages and between the sexes, separately addressing findings in observational studies and experimental hormone manipulations, and from plasma and fecal metabolites. This analysis could provide insight into the factors that influence hormonal regulation across vertebrates.

14-5 SCHOEPF, I*; MOORE, IT; BONIER, F; Queen's University, Kingston, Virginia Tech, Blacksburg; *is35@queensu.ca*

Effects of Malarial Infection on Reproduction and Offspring Phenotype in a Wild Passerine

Avian malaria is a widespread phenomenon, found in all avian orders and on almost every continent. While avian malaria has been linked to the decline of some insular birds, in most species its effects are sub-lethal. Several studies in captive and wild populations have shown that chronic, low intensity infections reduce survival and reproductive success of infected birds. However, it is unclear how infections in mothers affect offspring. We manipulated infection in wild red-winged blackbird mothers (*Agelaius phoeniceus*) and measured effects of experimentally reduced parasite load on reproduction of treated adult females as well as growth, physiology, and immune function of their offspring. In the wild, red-winged blackbirds are able to tolerate infection fairly well, breeding successfully and surviving across years. However, past work with individuals from this population in captivity has revealed significant costs associated with avian malarial infections. Birds at our field site experience an unusually high incidence of Haemosporidian infection (>90 % of individuals infected with 1 or more genus of Haemosporidian). To reduce infections, we caught adult females before onset of egg-laying, and treated them with anti-malarial medications or a control solution. Our results provide experimental evidence that decreased avian malarial infections lead to higher reproductive success in adult females and affect offspring quality and viability.

P1-268 SCHORNO, S*; GILLIS, T; FUDGE, DS; University of Guelph, Guelph, ON, Chapman University, Orange, CA; *schorno.sarah@gmail.com*

Refilling and emptying of hagfish slime glands: timeline for refilling and insights from slime exudate compositional changes

While there is much interest in the biochemical and biophysical properties of hagfishes' unique defensive slime, little is known about how long slime gland refilling takes, or how slime composition changes with refilling. The slime gland refilling process itself has yet to be examined, and while the mechanisms involved with release of the slime cells is understood, an examination of the exudate with successive stimulations of the slime gland has never been conducted. This study looked to characterize changes in the slime exudate during refilling, as well as with successive stimulations and emptying of the slime gland. Slime glands can be individually electro-stimulated to release slime, and this technique was utilized to conduct slime gland refilling trials. Slime gland refilling timelines were compared between two species, as well as between different body regions within a hagfish. Histological examination of empty and full slime glands was also conducted, and changes in the slime gland musculature was examined. The amount of exudate produced, composition of exudate, and morphometrics of slime cells were analyzed during refilling, as well as over emptying of full slime glands. Complete refilling of the slime glands was found to take three to four weeks in both species. There were also significant changes in the composition of exudate and morphometrics of slime cells during refilling. However, morphometrics did not significantly change with successive stimulations of full slime glands to exhaustion. Exhausted slime glands were found to still contain a small proportion of slime cells, and future studies should examine the cellular process of refilling within the slime glands via histological investigation.

P2-137 SCHRAIBER, JG; Temple University; *joshua.schraiber@temple.edu*

Asessing the Relationship Between Ancient and Modern Populations

Genetic material sequenced from ancient samples is revolutionizing our understanding of the recent evolutionary past. However, ancient DNA is often degraded, resulting in low coverage, error-prone sequencing. Several solutions exist to this problem, ranging from simple approach such as selecting a read at random for each site to more complicated approaches involving genotype likelihoods. In this work, we present a novel method for assessing the relationship of an ancient sample with a modern population while accounting for sequencing error and post-mortem damage by analyzing raw read from multiple ancient individuals simultaneously. We show that when analyzing SNP data, it is better to sequence more ancient samples to low coverage: two samples sequenced to 0.5x coverage provide better resolution than a single sample sequenced to 2x coverage. We also examined the power to detect whether an ancient sample is directly ancestral to a modern population, finding that with even a few high coverage individuals, even ancient samples that are very slightly diverged from the modern population can be detected with ease. When we applied our approach to European samples, we found that no ancient samples represent direct ancestors of modern Europeans. We also found that, as shown previously, the most ancient Europeans appear to have had the smallest effective population sizes, indicating a role for agriculture in modern population growth.

42-2 SCHROCK, TA; Walla Walla University; *Taylir.Schrock@wallawalla.edu*

Get a Whiff of This: Octopus rubescens responses to conspecific inking

Many social animals reduce the risk of predation by detecting signals of nearby conspecifics to alert them of potential threats. Such communication, however, is not limited to social animals. I hypothesize that octopuses, a non-social but highly intelligent marine invertebrate, may avoid predation by detection of conspecific inking. Metabolic rates of *Octopus rubescens* were used to determine detection of conspecific ink. Octopuses were exposed to concentrations of ink ranging from 0-0.004 mg/ml at random and ventilation and metabolic rates were measured. Metabolic responses appeared to vary with ink concentration in a dose dependent manner. Metabolic rates decreased from the negative control when subjected to more concentrated ink, but increased from the negative control when subjected to more dilute ink. This may account for the different octopus responses which may depend on the proximity of the inking event.

P3-227 SCHULTZ, DT*; EIZENGA, J; CHRISTIANSON, LM; FRANCIS, WR; CORBETT-DETIG, RB; GREEN, RE; HADDOCK, SHD; Univ. of California, Santa Cruz, Monterey Bay Aquarium Research Institute, University of Southern Denmark, Monterey Bay Aquarium Research Institute, Univ. of California, Santa Cruz; *dts@ucsc.edu*

Novel ORFs and Synteny Rearrangement of the Beroe forskalii Ctenophore Mitochondrial Genome

To date, only two ctenophore species' mitochondrial genomes have been sequenced. We assembled the mitochondrial genomes from three individuals of the ctenophore *Beroe forskalii* using Oxford Nanopore and Illumina data. The *Beroe forskalii* mitochondrial genome contains a conserved NAD2-like open reading frame, as well as a conserved ORF with unknown function. We use a Bayesian hypothesis test of codon usage and find that the unknown ORFs closely match the trinucleotide frequency of canonical mitochondrial genes rather than that of noncoding intergenic sequence. In addition, through simulations and measurements of piN/piS we find that the two unknown ORFs are under negative selection, indicating that they are functionally constrained. Lastly, through synteny analysis of these mitochondrial genomes, we find that mitochondrial rearrangements have occurred between every extant sequenced ctenophore lineage.

104-4 SCHUMM, MP*; EDIE, SM; WHITE, AE; COLLINS, KS; PRICE, TD; JABLONSKI, D; The University of Chicago; *mschumm@uchicago.edu*

Global Patterns of Functional Diversity and Community Assembly in Marine and Terrestrial Systems

Latitudinal gradients of biodiversity are a central focus of macroecological research in both terrestrial and marine systems. Functional diversity is an important facet of biodiversity linking species with the ecosystems that they influence and evolve within, but the relationship of this extra-taxonomic component of biodiversity to latitude and its environmental correlates is poorly understood. Here we compare spatial patterns of functional diversity in marine bivalves to those of a primarily terrestrial taxon, birds. Birds and bivalves are both taxonomically and functionally diverse and together have already been used to identify marine-terrestrial parallels in range size evolution. We used global data on bird and bivalve species-level ecological attributes to place them in multidimensional functional frameworks, and used species occurrence data to estimate changes in functional diversity with latitude, using motif analysis to explore gain and loss of functional groups (FGs) with latitude and habitat types. We found that both tropical bivalve and tropical bird faunas show high functional richness (FR) but low evenness (FE); species richness across tropical functional groups for both taxa follows a "hollow curve". The few FGs that persist toward the poles are more uniformly speciose, such that FR declines and FE rises with latitude. Ultimately, our analyses reveal large-scale parallels in marine and terrestrial systems, and suggest that the disparate FR and FE of the tropics in these systems is a consequence of unsaturated tropical faunas containing rare FGs.

105-7 SCHUPPE, ER*; FUXJAGER, MJ; UNIVERSITY, Wake; Wake Forest University; *schuer15@wfu.edu*

Comparative assessment reveals widespread capacity for androgenic signaling across peripheral tissues

Androgenic hormones act through androgen receptors (AR) to mediate many physiological processes in vertebrates. While the prevailing dogma is that ARs are expressed in nearly all nucleated cells, few studies have tested this idea to determine how the potential for androgenic signaling differs across peripheral tissues. Even less understood is how co-factors that interact with AR can act as dynamic rheostats to increase or decrease the capacity for androgenic signaling in tissues that perform diverse functions. Thus, little is known about how androgenic signaling capacity differs at the tissue and species level. We address these two questions by using two oscine passerines (northern cardinal and white-breasted nuthatch) and one sub-oscine passerine (blue-crowned manakin). Our findings not only show that AR expression differs among species, but there is also substantial variation among tissues. Meanwhile, our findings are consistent with the long-standing notion that AR is expressed in most tissues, but most enriched in tissues that perform essential reproductive functions. Additionally, co-factor expression differs between tissues. Tissue-level differences in co-factor expression likely provide alternative routes to modulate androgen targets outside of increased receptor sensitivity. Taken together, we provide the first detailed description that nearly all tissues across the body exhibit the capacity for androgen signaling, with substantial variation between species and tissues. We suspect that such variation is a product of different selection regimens, including sexual selection and drift, shaping androgenic signaling mechanisms in peripheral tissues.

P1-7 SCHWALBE, MAB*; HOWES, LJ; ROKOP, ME; Tufts University, Boston Harbor Cruises, UMass Boston; *margot.schwalbe@tufts.edu*

Turning Freshmen into Scientists: Analyzing Whale Watch Data in a First Year Seminar

First year students have few opportunities to directly experience the scientific process, read primary literature, and grapple with large datasets. In a unique marine-based seminar titled "Animal Survival in Extreme Environments", we used primary and secondary sources to survey animals by the different types of extreme environments they inhabit. Whales, in particular, span multiple extreme habitats and several whale species are seen locally in the Stellwagen Bank Marine Sanctuary (SBMS, north of Cape Cod, MA). For the midterm project, we tasked each student to design their own study and write a scientific paper using a large dataset of observational data collected during whale watch cruises to the SBMS. The dataset included three years of what, where, and when different whales were seen; what feeding, breaching, and traveling behaviors were observed; and if calves were present. Each student came up with a hypothesis and analyzed different portions of the data to test their hypothesis. We introduced them to the necessary skills in a stepwise manner, which included reading primary literature, writing an introduction, participating in peer review, analyzing data, and writing results. The 23 students (61% STEM majors, 39% non-majors) exceeded our expectations and student surveys indicated that 100% of the students were more confident in their data analysis skills and 83% were more confident in writing scientific papers upon completion of this challenging project. The stepwise approach we used was very effective with training this group of diverse students in the scientific process and familiarizing them with data analysis. Our pedagogical strategies can be adapted to other large datasets so that more first year students can have an authentic research experience in the classroom.

67-5 SCHWANER, MJ*; LIN, DC; MCGOWAN, CP; University of Idaho, Moscow (ID), Washington State University, Pullman (WA); *janneke.schwaner@gmail.com*

Muscle Dynamics in Jumping Kangaroo Rats (D. deserti)

Kangaroo rats (D. *deserti*) are bipedal hopping desert rodents that use vertical jumps to escape their predators (mainly owls and snakes). Previous research on the mechanics of these jumps indicates that the ankle is the main contributor to net joint work when comparing across jump heights. In addition, we found 30% of the net joint work measured at the ankle is transferred from proximal muscles via the bi-articular ankle extensors. Give these results, the lateral gastrocnemius (LG) muscle, a large ankle extensor, and the vastus lateralis (VL) muscle, a large knee extensor, likely both play important roles in propelling the animals up during vertical jumps. In the present study, we examined the in vivo performance of the LG and VL muscles during vertical jumping over a range of jump heights with the use of sonomicrometry and electromyography (EMG). We hypothesized that muscle shortening strain would be independent of jump height, but that relative EMG intensity would increase with increasing jump height. Preliminary data suggest that our hypotheses are supported. There appears to be a linear relationship between jump height and relative EMG intensity for both muscles, whereas net muscle shortening does not change. This suggests that the increase in mechanical work required to achieve higher jumps is likely due to great muscle force and not greater muscle length changes.

P3-246 SCHWARTZ, ML; MASLAKOVA, SA; PARTRIDGE, M*; STEBBINS, M; TILAHUN, T; HOLMAN, M; NORENBURG, J; University of Washington, Tacoma, Oregon Institute of Marine Biology, University of Oregon, National Museum of Natural History, Smithsonian Institution; *megansc@uw.edu*

Nemertean Diversity at Carrie Bow Cay, Belize

Current knowledge of distribution and biodiversity patterns of Caribbean nemerteans is exceedingly poor. There are 29 described Caribbean nemertean species, of which the majority (24) was described prior to the 1960s. However, in just two 2-week trips to Carrie Bow Cay, Belize, we could easily recognize at least 40 new and different morphospecies. This suggests that there is much greater nemertean diversity in the Caribbean than currently documented. We used visual identification and DNA barcoding, with both COI and 16S markers, to record the benthic macro-nemertean fauna around Smithsonian's Field Station at Carrie Bow Cay, Belize. Our results verify that there are many new nemertean species as well as several cryptic species complexes. Additionally, we were able to catalog prey items of several nemerteans in our barcoding efforts. These results will be combined with sampling efforts and DNA barcoding of nemerteans from Bocas del Toro, Panama to determine species boundaries and endemicity. Given the current climate change, the formidable amount of undocumented biodiversity, and dwindling funding for biodiversity and taxonomy studies, our combined approach of visual identification and DNA barcoding will accelerate efforts to catalog existing species.

51-4 SCHWEIKERT, LE*; FITAK, RR; GRACE, MS; JOHNSEN, S; Duke University, Florida Institute of Technology; *lorian.schweikert@gmail.com*

Dermal Photoreception May Provide Sensory Feedback for Dynamic Coloration

Dynamic coloration is the ability of certain animals to rapidly change the color of the body. Physiological investigation of this system has led to the hypothesis that color change, often for the purpose of camouflage, may at least be partially mediated by a light-sensing mechanism in the skin. The present work is the first to show that instead of serving as an environmental sensor, light reception by the skin may instead underlie a sensory feedback mechanism for color change. Here, the functional organization of dermal photoreception was investigated in the hogfish (*Lachnolaimus maximus*), a reef fish that undergoes dynamic coloration. In part, hogfish achieve skin color change via well-characterized movements of pigment granules within specialized cells called chromatophores. These pigment granules absorb short-wavelength light, dispersing and aggregating along a two-dimensional plane, giving hogfish their reddish-brown and pale-white color morphs, respectively. Here, transcriptomics revealed the expression of genes that could support distinct, yet complete phototransduction cascades in the retina and skin of *L. maximus*. In contrast to the genes encoding five opsin classes and a cGMP-dependent phototransduction cascade in the retina, a single short-wavelength sensitive opsin (SWS1) and putative cAMP-dependent phototransduction cascade were found in the skin. Anti-opsin immunofluorescence localized the SWS1 opsin underneath the layer of pigment within chromatophore cells. As such, aggregated pigment would allow incident light to activate the skin's SWS1 opsin, while dispersed pigment would obscure incident light, causing deactivation of the opsin during the skin's color-change response. This feedback mechanism could provide information about how the skin appears, in lieu of the animal observing its own body, to optimize color-change performance.

P1-6 SCHWEIZER, KG*; GEIGER, C; PILLOT, AN; MEADOWS, MG; Saint Francis University; *kgs104@francis.edu*

Bargain Jellies: Health and Survival of Moon Jellies (Aurelia aurita) in Hand-Built Pseudo-Kreisel Aquaria

Jellies are typically considered difficult organisms to raise in the lab by many scientists. This is due to their requirements for constant water current and the absence of corners. In the wild, jellies such as moon jellies (*Aurelia aurita*) rarely encounter habitats outside of the open ocean where they are part of the plankton, so they are not adapted to navigate obstacles or get out of small spaces such as the corners of aquaria. In order to conduct an experiment utilizing live moon jellies to assess their utility in bioremediation of oil spills, we designed and built 4 pseudo-kreisel aquaria to house our jellies using a limited budget and many readily-available materials. Here, we present the methods used to construct these aquaria inexpensively (important for undergraduate research!) and evidence of their effectiveness in long-term housing of live jellies so that other researchers interested in jelly research can construct similar housing. Briefly, we removed the corners from 10 gallon aquaria and also provided for continuous circular water currents by adding quarter pieces of the sides of 5 gallon buckets attached via silicon sealant. Current was provided by spray bars that provided even water flow in all areas of the aquaria, driven by pumps in the external sump and filtration systems. We built the sump/filtration systems using 5-gallon buckets containing bio-balls and filter floss. Water was delivered to the sumps via PVC overflow plumbed into the aquaria via a bulkhead set into the glass at the desired water level. The overflows were covered with a small piece of fine screen and directly behind the spray bars in order to prevent jellies from becoming stuck as water leaves the system for filtration. Results of husbandry including survival and indicators of jelly health such as pulsing rate and holes in their bells over approximately 3 months will be presented.

120-3 SCHWEIZER, RM*; VELOTTA, JP; IVY, CM; SCOTT, GR; CHEVIRON, ZA; University of Montana, McMaster University, McMaster University; *rena.schweizer@umontana.edu*

Selection on a master regulator of oxygen homeostasis contributes to adaptive hypoxia signaling in deer mice

The high-altitude environment, characterized by severe and unremitting hypobaric hypoxia, provides a unique testing ground for investigating the mechanisms of adaptation. Recent studies suggest that mammals living at high altitude tolerate low O_2 pressure by modifying a key hypoxia-signaling pathway known as the hypoxia-inducible factor (HIF) cascade. One gene that is consistently under positive selection in highland specialists is *Epas1*, a transcription factor and master regulator of the HIF cascade. Here we report the finding that highland and lowland populations of deer mice (*Peromyscus maniculatus*) exhibit extreme allele frequency variation at *Epas1*. Transcriptome scans indicate that these differences in *Epas1* allele frequency stem from a history of spatially varying selection between high and low altitudes. Subsequent genotyping in populations from multiple elevations across the western United States shows that *Epas1* allele frequency varies clinally with elevation. We characterized genotypic differences in the physiological response to hypoxia within an admixed population on the summit of Mt Evans, CO. We find that *Epas1* genotype influences heart rate under hypoxia, with homozygotes for the highland allele maintaining higher heart rate under severe hypoxia, which likely improves O_2 transport to metabolizing tissues. Moreover, we find that *Epas1* genotype also influences the expression of genes that may contribute to physiological responses to hypoxia. Our results indicate that selection on hypoxia signaling contributes to high-altitude adaptation in deer mice via modification to the regulation of the HIF cascade.

127-6 SCIOLI, J.A.*; FELDER, D.L.; University of Louisiana at Lafayette; *jas0409@louisiana.edu*

Does the evolution of symbiotic lifestyles affect diversification rate in marine crustaceans?

Marine crustaceans are spectacularly diverse, both taxonomically and ecologically. Many lineages of crustaceans have formed interspecific symbiotic relationships with a variety of marine organisms, including corals, fish, echinoderms, sponges, tunicates, and even other crustaceans. These symbioses include a wide array of interactions, from the cohabitation of burrows, to specialized fish cleaning behavior, to living inside the canals of sponges or the mantle cavities of bivalves. The evolution of these symbiotic interactions can potentially have significant effects on diversification rates. Here we investigate two mutually exclusive hypotheses. The first, the "dead-end hypothesis," suggests that symbiotic crustaceans are limited by their interaction with their host and therefore cannot diversify into new geographic or ecological spaces, i.e. symbiotic lifestyles represent an "evolutionary dead-end." The second, the "adaptive radiation hypothesis," suggests that the evolution of symbiotic lifestyles facilitates rapid radiation through the colonization of new host taxa. The former hypothesis predicts a reduced diversification rate in symbiotic lineages compared to their free-living relatives, whereas the latter predicts the opposite scenario. To test these hypotheses, we utilize published molecular phylogenies of eight groups of marine crustaceans, including snapping shrimp, pea crabs, and amphipods, among others, as case studies. We use multiple speciation and extinction (SE) models to compare diversification of symbiotic and free-living lineages in each case study and compare the results of different case studies and model types.

S9-10 SCOTT, Graham/R; McMaster University; *scottg2@mcmaster.ca*

Mitochondrial physiology and respiratory performance in high-altitude natives

High-altitude environments provide fertile ground for investigating the mechanisms and evolution of mitochondrial physiology and animal performance. The cold and oxygen-depleted (‘hypoxic') environment at high altitudes requires that endothermic animals sustain high rates of O_2 consumption for thermogenesis and locomotion while facing a diminished O_2 availability. I will present our work examining the ways in which high-altitude populations of deer mice (*Peromyscus maniculatus*) overcome these challenges and maintain respiratory performance through evolved changes in mitochondrial function. High-altitude mice have evolved an enhanced respiratory capacity (VO_2max) in hypoxia compared to their low-altitude counterparts, in association with increases in mitochondrial quantity, quality, and O_2 supply in the skeletal muscle. Increases in mitochondrial quantity arise from the combined effects of having greater abundances of oxidative muscle fibres and higher mitochondrial volume densities. Changes in mitochondrial quality, as reflected by changes in the capacity of mitochondria for supporting oxidative phosphorylation, also differentiate high- and low-altitude populations. Mitochondrial O_2 supply is augmented in high-altitude populations by changes in the intracellular distribution of mitochondria, such that more mitochondria are situated in a subsarcolemmal location adjacent to the cell membrane, and by a greater capillarity of muscle fibres. Our results therefore suggest that several evolved changes in mitochondrial function and O_2 supply contribute to respiratory performance at high altitudes. (Supported by NSERC of Canada)

64-4 SEARS, CR*; GROSS, JB; Univ. of Cincinnati; *searscr@mail.uc.edu*

The RNA Architecture of Life in the Dark: A Transcriptomic Assessment of Varying Photic Conditions in the Blind Mexican Cavefish, Astyanax mexicanus

Extreme environments frequently yield extreme characteristics in their inhabitants. The complex genetic changes that underlie these traits remain largely unknown. One extreme environment is the cave, which is marked by the complete absence of light. Here, we evaluate how varying lighting conditions influence gene expression in the blind Mexican cavefish, *Astyanax mexicanus*. These freshwater fish reside in 29 cave localities and countless surface localities in NE Mexico. Prior transcriptomic studies in this system have not accounted for photic rearing differences. To address this, we raised several cave and surface fish under 12:12hr light/dark conditions ("surface-like", LD) or constant darkness ("cave-like", DD) for 5+ years. Total RNA was extracted from head tissue, and poly-A primed, and subjected to Illumina HiSeq 2500 RNA-sequencing to a depth of ~10 million reads. Raw reads were aligned to the draft *A. mexicanus* genome to evaluate expression of 25,271 predicted genes. Intra-morphotypic gene expression changes were well correlated (R^2=0.9599), however analyses of morphotypes under their "natural" lighting conditions (C_{DD}xS_{LD}) yielded dramatic expression level differences (R^2=0.8597). A GO term analysis revealed many gene expression differences associated with ‘metabolism' and ‘response to stimuli'. Moreover, several uniquely expressed genes were identified, which may inform how cave animals are able to survive life in total darkness. In sum, this work reveals dramatic changes in the RNA architecture of cave and surface fish raised under different lighting conditions. This gene expression analysis, paired with genetic association studies, will help inform how complex changes to the genome enable organisms to adapt to extreme environments.

105-1 SEDDON, RJ; HEWS, DK*; Indiana State Univ.; *diana.hews@indstate.edu*

Do Plasma Levels of α-MSH or Steroid Hormones Correlate across Lizard Populations Varying in Melanization?

The concept of hormonal pleiotropy suggests facilitated, or constrained, evolution among a suite of hormone-mediated traits, and the melanocortin system has been one focus of work motivated by this endocrine concept. Melanocortins can regulate melanin synthesis and many other traits, and we studied relationships between melanization and plasma levels of three hormones: α-melanocyte stimulating hormone (α-MSH), testosterone and corticosterone. We compared both between- and within-population differences of adult male western fence lizards, *Sceloporus occidentalis* in California where individuals are increasingly darker at higher elevations. We studied five high- and four low-elevation populations, and worked during comparable periods of the breeding season at each site. Baseline plasma levels of α-melanocyte stimulating hormone (α-MSH) did not differ significantly among populations, but populations differed in means for both corticosterone and testosterone, although there was no consistent pattern with elevation or mean melanization for any hormone. Combining all individuals from the nine populations, we found that variation in α-MSH was not associated with variation in melanization, but that plasma α-MSH levels were positively associated with baseline plasma testosterone and negatively correlated with baseline corticosterone. Our results comparing across populations differ from a growing number of within-population studies of melanization, and we discuss hypothetical differences in endocrine mechanisms that could produce different trait correlation patterns. Our data suggest that hormonal pleiotropy does not constrain phenotypic variation, especially when considering the melanocortin system, with *in situ* synthesis of α-MSH by the skin and the diversity of melanocortin receptors.

134-6 SEGRE, PS*; CADE, DE; CALAMBOKIDIS, J; FISH, FE; FRIEDLAENDER, AS; POTVIN, J; GOLDBOGEN, JA; Stanford University, Cascadia Research Collective, West Chester University, University of California, Santa Cruz, Saint Louis University; *psegre@stanford.edu*

The role of flippers, flukes, and body flexibility in blue whale maneuvering performance.

Maneuverability is one of the most important but least understood aspects of locomotion. Because of their enormous size, blue whales (*Balaenoptera musculus*) are often characterized as highly stable, open-ocean swimmers who exchange maneuverability for long-distance cruising performance. However, recent advances in biologging sensors have revealed that blue whales use surprisingly acrobatic maneuvers for catching their prey. Yet, little is known about the performance limitations, the control, and the execution of these maneuvers. Using suction-cup attached multi-sensor tags equipped with cameras we investigated the timing and movement of the flippers, flukes, and body axis used by feeding blue whales (n=14) to perform a suite of simple and complex maneuvers. To perform longitudinal axis rolls, blue whales use asymmetric lift generated by the extended flippers, the flukes are not used, and the body does not flex or extend. Blue whales perform pitch changes by using their extended flippers to generate lift in conjunction with asymmetric fluke strokes and a flexed or extended body. Most yaw changes are performed by rolling the body into the direction of the turn and using a laterally directed, upward pitch change with a dorsally extended body. In contrast, while turning at the surface, blue whales use lower performance, non-banked turns performed by flexing their body laterally. To maneuver along complex trajectories, such as those used to perform a series of breaths or to approach and engulf their prey, blue whales combine sequences of simple maneuvers around the roll, pitch, and yaw axes.

P1-279 SEIDEL, R; HOSNY, A; FROLAND, J*; KNOETEL, D; FRATZL, P; WEAVER, JC; BAUM, D; DEAN, MN; MPIKG, Wyss Inst, Stanford U, Zuse Inst; *mason.dean@mpikg.mpg.de*

Quantitative shape analysis and mechanics of intertesseral joints in tessellated cartilage of sharks and rays

The cartilaginous skeleton of sharks and rays (elasmobranchs) comprises an unmineralized hyaline-like cartilage core sheathed in a tessellated layer of calcified cartilage, wrapped in a fibrous perichondrium. The tessellated layer is a composite, composed of minute, mineralized tiles (tesserae), anchored to one another and the surrounding tissue by a collagenous network. This tiled calcified layer allows for skeletal growth, but also provides rigidity to an otherwise flexible skeleton. However, our understanding of the mechanics of the macroscopic tiled composite is limited by the lack of knowledge of the structural interactions between tesserae. We use high-resolution SR-μCT, novel shape-based analysis algorithms and 3D printing to characterize the articulations between tesserae in round stingray Urobatis halleri. Although tesserae begin as isolated elements, they grow into contact as animals age: the resultant intertesseral joint is a complex architecture of unmineralized fibrous zones (where fibers connect adjacent tesserae) surrounded by flat regions of close contact, where tesserae are typically <2μm apart. Tesserae, unlike other natural tilings, neither overlap nor exhibit macroscopic interdigitations; we note, however, that subtle topographic features of contact zone surfaces are mirrored in adjacent tesserae. Coupled with the extreme proximity of neighboring tesserae, this creates an interlocking effect, which we verified with 3D printed tesserae. To further characterize this effect, we developed a mesh-based shape analysis protocol to evaluate local and global interlocking of adjacent tesseral edges, defining variables relevant to skeletal mineralization, as well as to the mechanics of tessellated cartilage and future bio-inspired tessellations.

P3-214 SELCER, KW; Duquesne University; *selcer@duq.edu*

Evolution of the Egg-Yolk Precursor Protein Vitellogenin in Sauropsids: Variation in Phosvitin Serine Composition and Codon Usage.

The egg-yolk precursor protein vitellogenin (Vtg) can be useful for studying evolutionary processes, due to its vital role in providing embryos of oviparous animals with energy and nutrients. Studies of Vtg evolution have focused on invertebrates and fishes and there is limited knowledge of this topic in tetrapods. Recent genome projects have provided Vtg sequences for a number of tetrapods, particularly birds. This study evaluates evolution of Vtgs in several sauropsid groups. The sauropsids have three Vtgs (1, 2, and 3), corresponding to VtgAB1, VtgAB2, and VtgAB3, using the terminology of the '3R hypothesis' of Vtg evolution. Vtg2 and Vtg3 share greater amino acid identity and cluster more closely together than to Vtg1, as determined by neighbor-joining analysis. Each Vtg has four distinct regions identified by conserved marker sequences: an N-terminal lipovitellin heavy chain, a phosvitin region containing many serine residues, a lipovitellin light chain and a C-terminal B'-CT region. For all species, Vtg1 is the largest and Vtg3 is smallest, with the differences due to the size of the phosvitin regions. Variation in the phosvitin region is largely due to the number of serine residues. Phosvitin serines have an altered codon usage compared to the other Vtg regions and to other proteins, favoring AGC and AGT. These data, and an analysis of serine codon repeats, are consistent with codon slippage as the means of altering serine numbers in the phosvitin region. Vtg1 and Vtg2 have more variation in serine number than does Vtg3. Codon slippage appears to provide a rapid mechanism for altering phosvitin composition. The functional significance of phosvitin serine variation remains to be determined. One hypothesis is that it may be related to the capacity of the phosphorylated serine residues to bind calcium ions.

115-5 SELCER, KW; Duquesne University; *selcer@duq.edu*
Vitellogenin as a Biomarker for Endocrine Disruption in Tetrapods: Evaluation of Its Utility and Potential.
A number of chemicals released into the environment mimic the action of the steroid hormone estrogen. These environmental estrogens pose potential health risks to humans and wildlife by disrupting physiological and developmental processes. Many laboratories have been using in vivo bioassays for environmental estrogens that are based on induction of the egg yolk precursor protein vitellogenin (vtg). The vast majority of vtg bioassays have been developed for fish species. In contrast, there have been few studies using vtg as a biomarker in tetrapods. My laboratory, in collaboration with others, has been developing tests for estrogenicity in tetrapods that involve evaluation of induction of the vtg protein in serum by specific immunoassays and the induction of hepatic vtg mRNA by RT-PCR. These vtg bioassays have been used for assessing endocrine disruption in a variety of tetrapods, including amphibians (tiger salamander, leopard frog, and African clawed frog) and reptiles (painted turtle, red-eared slider turtle, Loggerhead sea turtle, Olive Ridley sea turtle, and Morelet's crocodile). These studies have demonstrated both the utility and the limitations of vtg induction's use as a biomarker for endocrine disruption. Vtg bioassays in tetrapods are quite useful for studies of reproductive cycles and patterns, and they may also be used to reveal exposure to higher levels of endocrine disruptors. However, vtg induction in tetrapods may not be as sensitive to low levels of environmental estrogens as it is in fishes, especially where serum vtg is concerned. There is a need for new, preferably minimally invasive, tests of vtg mRNA induction to increase the sensitivity of tetrapod endocrine disruption assays.

137-2 SELCER, KW; Duquesne University; *selcer@duq.edu*
Use of Endocrine Disruption as a Framework for Laboratory Instruction of Basic Biochemical Methods.
A meaningful laboratory class on biochemical methods should not only demonstrate modern techniques, but should also provide an experimental context that intellectually engages students. Our department has been using a series of laboratory exercises that provides instruction in biochemical techniques within the context of an investigation of environmental endocrine disruption. The experiments evaluate serum vitellogenin induction as a biomarker for estrogen exposure. Male African clawed frogs are treated variously with natural estrogens, environmental estrogens, or vehicle. Serum samples, prepared from the frog blood, are used for the biochemical analyses. A Coomassie protein assay is first used to compare total serum protein levels among treatment groups. Differences in serum protein compositions, based on separation by molecular weight, are then compared among groups by SDS-PAGE. Proteins from control and treated groups are then separated by DEAE-chromatography, followed by vitellogenin Western blotting analysis of the serum samples and DEAE fractions, using a specific vitellogenin antiserum. Students then interpret their data on vitellogenin induction in the context of endocrine disruption. This series of experiments has been used for a number of years in our experimental biology laboratory course, and a more limited single laboratory experiment has been used to expose high school students to biochemical methods. The experiments can be expanded to include RT-PCR analysis of hepatic vitellogenin mRNA induction, or liquid chromatography-mass spectrometry of vitellogenin. Feedback from students has been generally positive. They particularly enjoy evaluating whether or not their experimental compounds are endocrine disruptors.

117-6 SELLERS, KC*; MIDDLETON, KM; HOLLIDAY, CM; SELLERS, Kaleb; Univ. of Missouri; *kcsty5@mail.missouri.edu*
Biomechanics and Evolution of the Crocodyliform Skull
The flat, akinetic skull of crocodyliforms evolved from the tall, kinetic skull of basal suchians, resulting in a reorganization of the feeding apparatus. This transformation was associated with the expansion of the pterygoid buttress, cranial flattening and rostral elongation, reorganization of the jaw joint, and the acquisition of a secondary bony palate and the loss of kinesis. Although the pattern of morphological change is recorded by fossils, the biomechanical performance of these transitional structures is less understood. These phylogenetic shape changes are to a degree mirrored by extant crocodylian ontogeny. Both ontogenetic and evolutionary shape changes result in reoriented muscles and presumably cranial forces, however these remain unclear. In order to assess how changing muscle orientation affects the magnitude, locations, and orientations of cranial forces, we used CT data to create 3D biomechanical models of an ontogenetic sequence of individuals of *Alligator mississippiensis* and individuals of select fossil suchians representing the stages in the acquisition of the crocodyliform skull. Dissections and osteological correlates informed muscle attachment reconstruction. We simulated unilateral bites under various bite locations and gape angles. With this dataset, we found that the pterygoid buttress appears to be loaded to a similar magnitude as the jaw joint in crocodyliforms. We found that over both ontogeny and evolution, joint force is aligned with the body of the quadrate. We found that as bite location moves caudally, working side joint force decreases in magnitude; it is likely that in extreme feeding events such as shaking bites or death roll, the jaw joint is loaded in tension. These results stand in contrast to the paradigm derived from studies of the mammalian feeding apparatus, in which a single jaw joint is loaded solely in compression.

90-4 SEPP, T*; GIRAUDEAU, M; MCGRAW, K; KAASIK, A; Arizona State University, University of Tartu; *tuul.sepp@gmail.com*
Does City Living Lead to Slower Pace of Life: Urban Impacts on Avian Life-History Evolution
The concept of a pace-of-life syndrome describes inter- and intra-specific variation in several life-history traits along a slow-to-fast pace-of-life continuum, with long lifespans, low reproductive and metabolic rates, and elevated somatic defences at the slow end of the continuum and the opposite traits at the fast end. Previous studies have shown that pace-of-life can vary in relation to local environmental conditions (e.g. latitude, altitude). I propose that this may also occur along an anthropogenically modified environmental gradient. I present the results of a statistical meta-analysis of two key traits related to pace-of-life, survival and breeding investment (clutch size). These results indicate that birds generally have higher survival, but smaller clutch sizes, in urban habitats. I also analyzed the literature on other traits related to reproductive investment and self maintenance that could be affected by changes in pace-of-life resulting from urbanization. I found that urban birds tend to produce lower-quality sexual signals and invest more in offspring care. Levels of nutritional or hormonal stress in birds do not seem to vary consistently as a function of urbanization, which is consistent with the hypothesis that birds can adapt or acclimate to certain aspects of the urban habitat. As a consequence of slower pace-of-life in urban habitats, differences in age structure should arise between urban and rural populations, providing a novel alternative explanation for physiological differences and earlier breeding recorded in urban animals. I also present preliminary results from a field experiment designed to reveal the possible changes in pace-of-life in response to urbanization in a model organism of urbanization research, the house finch (*Haemorhous mexicanus*).

142-7 SERGEY, baranov; University od Vladimir;
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Hidden Asymmetry in Shape of Biological Patterns

he asymmetry is studied on different biosystemic levels. The deviation from perfect bilateral symmetry is a phenomen, which mean the turns in metabolic paths responsible for developmental homeostasis. There is an importance of unbiased estimates of asymmetry. Present study demonstrates as accuracy of measurement indicates the statistically significant presence of directional asymmetry (DA) in leaf blade of Betula pendula. Twelve landmarks were employed in every leaf blade and Procrustes analyze of variance was used. The random measuring error was determined by repeated photographing and two-fold application of landmarks on each image. In ten randomly selected populations DA was revealed in all biosystem level from the population to leaf blade level. Populations did not show significant difference in DA value. Two-factor interaction "leaf × side" showed the statistical significance on all levels as well. The directional asymmetry of metric traits corresponded to the value directional asymmetry in leaf blade shape. Results revealed the DA highly varied in individual (tree level) whereby population characteristic remain invariant. DA as a genotypic component of asymmetry variety can be concluded about high heterogeneity of genotypic effect in individual level across all populations. The high accuracy of measurement error allows to detect DA variance as a genetic component variability on intra and inter individual levels. So directional asymmetry can be characterised as a common type of bilateral asymmetry presented in the shape of birch leaf blades. Fluctuating asymmetry in its pure form, at all levels of biosystem was met only in single population of ten that should be taken into account in testing developmental stability of birch and possibly other woody plants. Keywords— developmental instability, directional asymmetry, fluctuating asymmetry, geometric morphometrics, silver birch.

68-1 SEROY, SK*; GRÜNBAUM, D; University of Washington;
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Individual and population level effects of ocean acidification on a model predator-prey system: bryozoan - nudibranch interactions in the Salish Sea

Ocean acidification (OA), resulting from increased oceanic CO_2 concentrations, causes a suite of chemical changes that present significant environmental stress for calcifying organisms. OA effects may potentially be synergistically amplified or reduced by species interactions as they propagate up to population and community levels, altering effects predicted by studies of calcifier responses in isolation. The colonial calcifying bryozoan, *Membranipora membranacea*, and the predatory nudibranch, *Corambe steinbergae*, present a unique model system to explore effects of OA on predator-prey interactions at multiple levels. *Membranipora* colonies exhibit a quantifiable inducible defense, protective spines on newly calcified zooids, on chemically detecting *Corambe*. OA effects on prey growth and defenses were quantified across a wide range of pH (7.0 to 7.9) with or without waterborne predator cue. Following exposure, predation rates were assessed by quantifying zooids consumed by *Corambe* over a 24-hour period. Consistent with previous studies, bryozoan colonies exhibited maximum growth at moderately low pH. Spine formation continued at pH values as low as 7.0. While predator responses were variable, preliminary results suggest that predation rates on undefended colonies may be unaffected by pH. However, in defended colonies, spines formed in low pH may confer less advantage than those formed in ambient conditions. A population dynamics model, used to compare spatial distributions of *Membranipora* under various combinations of predation pressure and acidification, suggests interactions between these stressors experienced earlier in the season may be more influential in determining demographic patterns as space competition is intense.

P1-57 SERRANO, S.*; PALACIOS ALVAREZ, J.; PAPA, J.; ITAGAKI, H.; Kenyon College, Thiel College; *itagaki@kenyon.edu*

Expression of FMRFamide in the midgut of larval Manduca sexta (Lepidoptera: Sphingidae) over development with different diets

The role of the enteric nervous system (ENS) and its relationship to microbiota and organismal health has become current topics of investigation. We have used the model insect, larval *Manduca sexta*, to begin some preliminary investigations of the roles of diet and microbiota in the expression of the neuropeptide FMRFamide using immunocytochemistry. We manipulated the diet by feeding the larvae on an artificial diet (Carolina Biological Supply) and on tomato leaves, as well as on a sterile artificial diet in a sterile environment to examine their effects over development on the expression of FMRFamide-like immunoreactivity. Our preliminary results indicate that there is a decrease in FMRFamide-like expression in the *M. sexta* gut on both natural and artificial diets over time. We have also found that *M. sexta* reared under sterile conditions had increased expression of FMRFamide-reactive cells compared to their non-sterile condition counterparts. These preliminary results suggest FMRFamide may play a role in earlier stages of gut development and that the ENS responds actively to the possible absence of enteric microbiota. Funded by: Kenyon College; Kenyon College Summer Science Scholarships and NSF-REU #1560005

P2-218 SETHI, A*; SELLERS, KC; COST, IN; MCGECHIE, F; MIDDLETON, KM; HOLLIDAY, CM; University of Missouri;
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3D Fiber Tracking of Jaw Muscles Reveals a Diversity of Muscle Architectures in the Heads of Reptiles.

Jaw muscles are important components of the vertebrate skull in that they drive feeding behavior by loading and moving the jaws. Jaw muscles present a variety of morphologies and functions that lend insight into behavior and evolution. However, it remains challenging to describe the 3D architecture of jaw muscles using classical 2D dissection-based methods or costly MRI-based methods. Therefore new methods in visualizing and measuring 3D muscle architecture are welcome. This study uses diffusible iodine contrast-enhanced CT (diceCT) to visualize muscle morphology and reconstruct the 3D architecture of jaw muscles using fiber-tracking software in order to determine functional differences in reptile jaw muscles. We sampled a simple muscle, m. intermandibularis, a more complex muscle m. pterygoideus and other neighboring jaw muscles in Tokay gecko (Gekko gecko) in order to test computational approaches. We immersed a gecko head in Lugol's Iodine solution in order to increase the contrast of muscles for microCT. We segmented the muscles and imported the models into Image3d.exe software. 3D orientations of individual fibers were visualized in MATLAB and further analyzed in R. We found the mpterygoideus muscle possesses a diversity of differently-oriented muscle fibers whereas m. intermandibularis was simpler suggesting these approaches work. This is the first 3D visualization of jaw muscle fibers in the heads of reptiles and one of the first to incorporate computational techniques with our new diceCT imaging protocols. This work will enable us to better understand the diversity, function and biomechanical significance of jaw muscles in the skulls of animals.

50-3 SETTON, EVW*; SHARMA, PP; University of Wisconsin-Madison; *setton@wisc.edu*

Is the function of the Wnt-1 co-receptor arrow conserved in segmentation of insects and arachnids?

Segmentation is a key characteristic of the phylum Arthropoda and linked to the evolutionary success of this lineage. The formation of segments requires the activity of the Wnt family of secreted proteins, as inferred from functional data in model organisms such as *Drosophila melanogaster* (fruit fly) and *Tribolium castaneum* (flour beetle). Comparable data are, however, limited in lineages like Chelicerata (e.g., spiders, mites), the sister group to the rest of the arthropods. Here we examined the inhibition of canonical Wnt signaling in the cobweb spider *Parasteatoda tepidariorum* using parental RNA interference against the single-copy *Wnt-1* co-receptor *arrow* (*arr*; vertebrate homolog: *LRP5* and *LRP6*), which is known to be a key member of the canonical Wnt-signaling pathway in holometabolous insects. We describe defects in germband formation and segmentation incurred by *arr* knockdown in developing spider embryos, using cell division, segment boundary, and apoptosis markers to assess the effect of the knockdown. We additionally compare our data to known phenotypes in the fruit fly and the flour beetle toward evaluating the conservation of *arr* function across insects and arachnids.

99-3 SEWALL, KB*; NARDINI, C; KOPPEN, J; BECK, ML; Virginia Tech, The College of New Jersey, Rivier College; *ksewall@vt.edu*

Lead exposure compromises song learning and bill coloration in male zebra finches

Lead exposure has been a major public health concern for decades, but recent research has highlighted the extreme vulnerability of the developing brain to even very low levels of lead. Few experimental studies have directly measured the effects of lead on learning. Songbirds provide an opportunity to examine the impacts of early lead exposure on learning, because they are a model for studying cognition and they learn their songs. In addition to song, many birds possess other condition-dependent traits, such as ornamental coloration, that could be susceptible to lead exposure and like song, have ramifications for future reproductive success. To resolve how lead exposure may impact learning, we reared 40 zebra finches in captivity and exposed them to levels of lead in water within the range reported in Flint, MI [high (1000 ppb, n=12) or moderate (100 ppb, n=16)], or reared them under control conditions (n=12). We then compared the songs of male birds against those of their tutors to assess their vocal learning and evaluated all birds in a motoric and a spatial cognition task. Finally, we measured bill coloration in male birds to infer potential impacts on reproductive success that are independent of song learning. We found that males exposed to lead imitated tutor song less precisely than controls indicating impaired learning. We detected no differences in motoric or spatial learning among treatments but found that males exposed to lead had brighter, yellower beaks than control males. These preliminary data demonstrate that exposure to lead in water compromises subtle measures of song learning and may also impact male attractiveness to females.

11-1 SHAH, A.A.*; GHALAMBOR, C.K.; SHAH, Alisha; Colorado State University; *alishas0624@gmail.com*

Do Temperature-Mediated Predator-Prey Interactions Explain Temperate and Tropical Mayfly Distributions?

Temperature is often implicated as a primary mechanism driving species turnover across elevation gradients. Janzen's climate variability hypothesis posits that the seasonal temperature variation experienced across temperate mountains should favor the evolution of species with broad thermal tolerances, greater dispersal ability, and wider elevation range sizes. Tropical mountain species should evolve narrower thermal tolerances in response to stable temperatures, restricted dispersal across elevation, and narrower range limits. Previously, we demonstrated that tropical aquatic insects have narrower thermal breadths (CTmax - CTmin) and lowered acclimation ability compared to their temperate relatives. However, thermal breadth alone does not adequately explain the abrupt cessation of one species' occurrence and the beginning of another's in certain streams sites. We therefore propose that important biotic interactions, such as predation, mediated by temperature, may play a role in determining mayfly elevation range limits, and explain the observed pattern of species turnover. We tested this hypothesis by artificially simulating range expansions of low elevation mayflies to high elevation streams and high elevation mayflies to low elevation streams, in a lab setting. "Transplanted" mayflies were exposed to suboptimal temperatures in the presence of native stonefly predators. Survival of transplanted mayflies was measured after 24h and compared to that of native mayflies in the same testing arena. We predicted that transplanted mayflies would be preyed upon more heavily than native mayflies because lowered performance in response to suboptimal temperatures would exacerbate their susceptibility to the predators. We also predicted that this effect would be stronger in the tropical species where thermal breadths are even narrower.

92-4 SHAHANDEH, MP*; PISCHEDDA, A; TURNER, TL; Univ. of California, Santa Barbara, Barnard College, Columbia University; *shahandeh@lifesci.ucsb.edu*

The genetic evolution of reproductively isolating male pheromone preference in Drosophila simulans and sechellia

Differences in mating behaviors are a common mechanism preventing mating between species. However, little is known about how mating behaviors become different between species, at the genetic or neurological level. In *Drosophila*, pheromones act as important species-specific signals that prevent hybridization. In *D. sechellia*, females express the pheromone 7,11-heptacosadiene (7,11-HD); *D. simulans* females express a different pheromone. *D. sechellia* males are stimulated to court by 7,11-HD. But for *D. simulans*, 7,11-HD suppresses courtship behavior. Because these species overlap in range, male pheromone preference is the primary mechanism preventing hybridization, accounting for ~71% of the gene flow restricted between them. We have harnessed this difference in pheromone preference, in combination with next generation DNA sequencing technology, to identify the genetic basis of male pheromone response. We have mapped a majority of the difference (~61%) in pheromone preference to a small region on a single chromosome, suggesting that sexual isolation may be attributed to a small genomic region with large effect. This locus also controls other aspects of male courtship behavior, like latency and investment. This implies that substantial mating barriers can evolve via changes to just a couple genes, rapidly isolating populations. We will present the results of our efforts to fine-map this region and test a widely-studied gene of interest, expressed in the developing fly brain, for its role in behavioral divergence. We aim to provide an in-depth study of the mechanisms underlying the evolution of a reproductively isolating behavior—a necessary goal of behavioral research, so that we may uncover general patterns in the changes underlying evolutionary shifts in behaviors that isolate species.

5-4 SHAHAR, R*; ZELZER, E; ZASLANSKY, P; OFER, L; Hebrew University , Weizmann Institute , Charité - Universitätsmedizin, Hebrew University; *ron.shahar1@mail.huji.ac.il*

Novel Form of Modeling Bypasses the Need For Osteocytes in the Adaptation of Bones to Mechanical Loading

Bone is a tough tissue, subjected to repetitive and cyclic loading throughout life. In the absence of proper adaptation to changes in loads, bones will be destined to fail due to damage accumulation. To avoid failure, bone-forming cells (osteoblasts) and bone-resorbing cells (osteoclasts) are continuously reshaping (model) and repairing (remodel) bone material. The main orchestrators of these synergetic processes are osteocytes, which constitute more than 90% of all bone cells. Considering the pivotal role of osteocytes , it is surprising that while bones of all vertebrates, including basal fish, contain a huge network of osteocytes, the bones of most extant fish completely lack them (anosteocytic bones). This raises questions regarding the ability of anosteocytic bones to adapt to loads or to regulate adaptation. We show remarkable response of anosteocytic bones to loading, such as osteoblast recruitment and architectural changes. Despite the lack of osteocytes, we detected expression of the main modeling-regulating gene, SOST (normally expressed exclusively by osteocytes), in peripheral cells such as osteoblasts and chondrocytes. Macro-to-nano structural and mechanical studies revealed similarity of adaptive response in both osteocytic and anosteocytic fish bones. To our surprise, not only is the adaptive response similar, but osteocytic bones of basal fish also express SOST by their peripheral cells - similarly to what we found in anosteocytic bones. Our findings suggest a novel form of modeling-control in fish bones, which differs from that of other vertebrate groups and might explain the evolutionary shift toward anosteocytic skeleton in fish.

P1-124 SHAHID, R*; GILL, PG; HOFFMANN, S; NYIT College of Osteopathic Medicine, Old Westbury, USA, University of Bristol, UK; *rshahid@nyit.edu*

Variation in Inner Ear Morphology of Early Mammaliaforms

The inner ear has undergone marked transformations in Mesozoic mammaliaforms, culminating in extant therians with greater ranges of hearing frequencies than most vertebrates. This ability has been associated with the elongation and coiling of the cochlear canal following the loss of the lagenar macula, ossification of the primary and secondary laminae, and ossification of the cribriform plate. The acquisition of these features in the few documented taxa appears mosaic, but could this reflect intraspecific or interspecific variation? To test whether cochlear canal length and curvature, presence of a lagenar macula, and ossification of laminae was variable in early mammaliaforms we micro-CT scanned 37 isolated petrosals of the basal mammaliaform *Morganucodon* from two Early Jurassic Glamorgan fissure fills. The endocasts reveal that the cochlear canal is short and fissure-specific with the average lengths ranging from 1.82 mm to 2.06 mm. In all specimens, the apex is gently curved and expanded, suggesting the presence of a lagenar macula. None of the specimens preserve ossified laminae, but a shallow groove is visible on the reconstructed endocasts, extending from the base of the canal, between the perilymphatic foramen and the fenestra vestibuli, to the apex. A similar groove for the base of the secondary osseous lamina is variably present in extant monotremes. Our qualitative data suggests the presence of a lagena and variation in cochlear length in *Morganucodon*. Interestingly, this variation is linked to different fissures and might represent variation in different populations or possibly in different species within *Morganucodon*. Quantitative assessment of cochlear shape using 3D geometric morphometrics is ongoing.

93-2 SHANKAR, A*; MORALES, AC; URGILES, GMU; CORDOVA, GKC; CISNEROS, INH; TINOCO, BA; GRAHAM, CH; POWERS, DR; Stony Brook University, NY, USA, McGill University, Montreal, Canada, Universidad del Azuay, Cuenca, Ecuador, Universidad del Azuay, Cuenca, Ecuador, George Fox University, OR, USA, WSL, Birmensdorf, Switzerland; *nushiamme@gmail.com*

From Shallow to Deep: A Torpor Spectrum in Hummingbirds

Controlled nighttime hypothermia (reduction in body temperature and metabolic rate) has been described in many bird and mammal species. In hummingbirds, all past studies show exclusive use of deep torpor where body temperature drops with ambient temperature down to a minimum body temperature that seems to be species-dependent. As hummingbirds normally have among the highest metabolic rates of all vertebrates, maximizing their energy savings at night by maximizing the use of deep torpor seems an efficient energy management strategy. However, two potential disadvantages of deep torpor are higher risk of predation, and less time to gain the restorative advantages of sleep. Indeed, not all hummingbird individuals or species use deep torpor every night. While carrying out torpor measurements using nighttime respirometry experiments, we found evidence to suggest that some hummingbird species use a ‘shallow' form of controlled hypothermia, where they drop their body temperature by only a few degrees on some nights, and use full torpor on other nights. Use of shallow controlled hypothermia was also supported using thermal imaging at night to record hummingbird surface temperatures. From this combination of respirometry and infrared imaging (all under near-natural conditions) on 16 hummingbird species in Arizona and the Ecuadorian Andes, we found that some species seem capable of using both shallow and deep torpor. If hummingbird torpor is on a continuum with sleep, this could have useful implications for our understanding of how hummingbirds balance the use of controlled hypothermia for energy savings with the need for restorative sleep.

P2-59 SHANNON, RP*; BOLEK, MG; Oklahoma State University; *shannrp@okstate.edu*

Trypanosome Isolation From Frog Blood Using Anion Exchange Chromatography

The genus *Trypanosoma* consists of flagellated protozoans that infect the circulatory system of all classes of vertebrates. Trypanosomes display a high level of morphological diversity, both between species and within the life cycle of a single trypanosome species. Additionally, a single host individual can be infected with multiple trypanosome morphotypes, and it is unclear whether these morphotypes represent distinct species or a single polymorphic species. To address this, we sequenced the 18s rRNA gene from 5 trypanosome morphotypes infecting amphibians in Oklahoma, USA. However, because the 18s rRNA gene is a multiple copy gene, it is unclear whether we are recovering genes from different trypanosome species, or if we are sequencing different copies of the 18s rRNA gene within a single trypanosome genome. In order to definitively determine the species associations, we need to isolate individual trypanosome morphotypes, and sequence a single copy gene from each morphotype. DEAE cellulose is an anion exchange chromatography resin that can be used to separate trypanosomes from whole blood samples based on differences in their cell surface charge. Trypanosomes are more positively charged than host blood cells, and when blood is added to the chromatography column, trypanosomes pass through the column, while the negatively charged blood cells stick to the positively charged column. Here we describe the use of anion exchange chromatography to isolate trypanosome morphotypes from whole blood. We are in the process of refining the technique and amplifying DNA from separated trypanosome morphotypes, with the overall goal of sequencing the gGAPDH gene of 11 different trypanosome morphotypes infecting Oklahoma amphibians.

50-7 SHARMA, PP*; NOLAN, ED; University of Wisconsin-Madison; *prashant.sharma@wisc.edu*

Shared Expression Patterns of Paralogous Genes Support a Derived Placement of Scorpiones in the Arachnid Tree of Life

The phylogenetic position of Scorpiones and the attendant evolutionary scenario of arachnid terrestrialization remain an unresolved puzzle for arthropod biologists. Datasets of morphologists and paleontologists typically recover scorpions at or close to the base of the arachnid tree of life, whereas molecular sequence data have recovered support for a clade comprised of scorpions and tetrapulmonates (groups united by a respiratory organ called the book lung). To adjudicate between these competing hypotheses using an independent data class, we conducted bioinformatic surveys of arachnid genomic resources and identified genes duplicated in both spiders and tetrapulmonates, to the exclusion of arachnids like harvestmen and mites. Focusing on a subset of genes that pattern appendages, we surveyed expression patterns of each paralog in developing embryos of the Arizona bark scorpion *Centruroides sculpturatus*, and compared these to spider and harvestman homologs. Here we show that multiple pairs of paralogs share distinct expression patterns in spiders and scorpions, whereas the harvestman and mite single-copy orthologs reflect the ancestral pattern observed in mandibulate and/or onychophoran counterparts. Together with analyses of gene tree topologies and Bayesian branch length ratios of the paralogs, our results show that independent sub-/neofunctionalization events unite scorpions and tetrapulmonates to the exclusion of the apulmonate arachnids.

P1-267 SHARMA, N*; YAWAR, A; BHULLAR, BAS; VENKADESAN, M; Yale University, CT, USA; *neelima.sharma@yale.edu*

To move or not: Principal curvatures of articular surfaces

The movement of synovial joints in vertebrates is determined by the surface geometry of adjoining bones and the attachment pattern of surrounding ligaments. Studies on the mechanics of joint motion are mostly descriptive comparisons or detailed computational models; a predictive geometric theory is lacking. Here we present work-in-progress of a mathematical technique to predict movement capability at the joint from considerations of principal curvatures of the articular surfaces. Joint anatomy enables only specific combinations of rotations and translations and not others e.g., the elbow rotates like a hinge whereas the base of the human thumb resembles a universal joint with two degrees of freedom. Joint motion is the outcome of the competition between ligament stretching versus articular cartilage compression. This competition may be mathematically approximated by a separation-dependent energy functional for the articulating surfaces. Minimizing the energy functional gradient shows that the softest mode of sliding between two congruent tori corresponds to the direction of the minimum principal curvature. Because general curved surfaces in 3D are parametrized by two principal curvatures at every point, i.e. locally they resemble a torus, our technique can be extended to the analysis of general articular surfaces. Ongoing work aims to validate our technique by predicting motions for reconstructed µCT scans of vertebrate joints (e.g. Monodelphis knee) and comparing them against in vivo motion. This work has implications for functional predictions of fossilized joints and the design of prosthetic and robotic joints.

P1-265 SHARP, AC*; DUTEL, H; CRUMPTON, N; FAGAN, MJ; EVANS, SE; University Collage London, UK, Univ. of Hull, UK; *a.sharp@ucl.ac.uk*

The Role of Soft Tissues in a Biomechanical Model of the Rat Cranium

Normal cranial growth and development rely on appropriate tissue interactions. Soft tissues like the brain and eyes develop first, becoming enclosed by fibrous capsules (e.g. periosteum, dura) within which the skeletal units develop, and are maintained and shaped. However, with the exception of the jaw muscles, most biomechanical models do not take into account the influence of soft tissues on patterns of cranial strain. Previous work has highlighted the need for a more comprehensive analysis of the biomechanical role of cranial soft tissues in both reptiles and mammals. We aim to clarify and quantify the role of apparently passive cranial soft tissues, including the brain, skin, eyes, sutures, and fascia, in a rat biomechanical model. Using 3D computer-based mechanical simulations based on micro-CT and detailed muscle dissections, we combined multibody dynamics analysis and finite element analysis to investigate and compare strains in skulls with and without soft tissues. The model was also validated against bite force data collected in vivo. Sutures redistribute cranial strain and have a greater effect on both strain magnitude and distribution than other soft tissues. Our model showed that including anatomically detailed sutures is important for modelling cranial strain. However, more research is needed to fully understand their significance, including comparisons with other species and juvenile individuals. Future research will aim to determine the relative significance of different soft tissues in reptiles versus mammals. We predict that soft tissues may play a greater overall role in the frame-like skulls of reptiles.

124-6 SHEPPARD, KA*; CARON, JB; RIVAL, DE; Queen's University, University of Toronto; *k.sheppard@queensu.ca*

On the Hydrodynamics of Anomalocaris Tail Fins

The arthropod *Anomalocaris canadensis*, described from the 508 million-year-old Burgess Shale site, is considered the apex predator of the Cambrian period with its prominent compound eyes, grasping appendages, and circular mouth with serrated teeth. The lateral lobes along its dorso-ventrally flattened body have traditionally been attributed to undulatory propulsion although the role of its unusual fan-like tail remains poorly understood. Swimming efficiency and manoeuvrability deduced from hydrodynamic analysis may provide information about predatory habits and how swimming mechanisms have evolved over time. The current study involves analysis of a three-vane model designed to mimic the tail fin to estimate the likely modes of locomotion. Through direct force measurements and stereoscopic particle image velocimetry, it was found that the geometry exhibited a region of steady-state lift and drag enhancement at angles of attack greater than 25° when compared to an equivalent delta-wing plate. These shapes showed little difference during acceleration from rest; however, at an angle of attack of 30° the lift and drag on the multi-vane model were 15.3% and 17.0% higher than the delta-wing model, respectively. It was found that the secondary and tertiary vanes of the tail-fin abstraction encourage the formation of additional leading-edge vortices, similar to those frequently seen on natural propulsors. The formation of these leading-edge vortices is confirmed by the increase in streamwise circulation measured near the additional leading edges along the length of the chord. The results of the current study suggest that the enhanced resultant normal force on the tail fin of *Anomalocaris* made it well-suited for manoeuvres, giving it the ability to turn quickly through small radii of curvature.

106-8 SHERO, MR*; KIRKHAM, AL; COSTA, DP; BURNS, JM; University of Alaska, Anchorage, University of California, Santa Cruz; *mrshero@alaska.edu*

Iron Mobilization During Lactation Draws from Aerobic Dive Capacities in Weddell seals: A Previously Unexplored Cost to a Capital-Breeding System

In marine mammals, there is profound energetic transfer from female to pup during lactation, when capital breeding females can lose >30% of their body mass and pups triple in size. In addition to fat and calories, milk also transfers many essential nutrients. For deep divers that rely on large tissue O_2 stores to support foraging efforts, maternal transfer of iron is critical to neonatal heme development. However, iron transfer may pose additional reproductive costs to the female if her endogenous reserves are depleted, compromising dive capacity. To assess this potential cost, we handled reproductive Weddell seals (*Leptonychotes weddellii*; n=143; at start and end of nursing, and postweaning) and compared their iron stores to those of 148 non-lactating females. During lactation, females' circulating iron levels were significantly higher than in non-lactating seals (P<0.001; 266±10 vs 122±7µg/dL), and iron binding proteins were also elevated (Ps<0.001 transferrin saturation: 64±2 vs 44±2%; ferritin concentration: 191±18 vs 96±12 ng/mL), suggesting iron was mobilized from endogenous stores. Serum iron levels were positively correlated with milk iron content (P<0.001), and Weddell seal milk contained 150-fold and 5-fold more iron than milk from other terrestrial and marine mammals, respectively. Mobilizing endogenous iron to milk appears to deplete reserves, and adult female hemoglobin and myoglobin levels declined soon after weaning, reducing total body oxygen stores and aerobic dive capacities (pre-weaning: 130±2mLO_2, post: 107±2mLO_2 lean kg^{-1}, P<0.001). This study shows that iron transferred from mother to pup during lactation reflects a previously unexplored cost to the capital breeding strategy.

P2-17 SHERO, MR*; ADAMS, GP; MCCORKELL, RB; KIRKHAM, AL; BURNS, JM; University of Alaska, Anchorage, University of Saskatchewan, University of Calgary; *mrshero@alaska.edu*

Weddell seal Reproductive Phenology Challenges the Notion that All Pinnipeds have Embryonic Diapause

Weddell seals (*Leptonychotes weddellii*) give birth from October to November and ovulate at the end of lactation (5-6 weeks later). Pinnipeds characteristically experience an embryonic diapause that lasts 1-4 months before proceeding with active gestation; however, our work challenges this notion in Weddell seals. From 2014-2017, we used transrectal ultrasonography to assess the reproductive phenology of prime-age adult Weddell seals at the time of ovulation (n=21; mid-November/mid-December) and when embryo implantation was thought to occur (n=82; mid-January/mid-February). Post-partum females, and seals that did not give birth that year (i.e., "no-birth") were handled at both time points. By late November no-birth females had ovulated, defined by a well-perfused corpus luteum, while 40 days post-partum females were still pre-ovulatory, with large antral follicles. By mid-January/mid-February, 80% of post-partum and 85% of "no-birth" seals were detectably pregnant. Based on anatomical features such as crown-rump-length, fetal heart rate, placentation, and organogenesis, pregnancies were estimated to be between ~7-75 days gestational age. Embryo growth curves were constructed and used to calculate when embryo implantation occurred, placing the start of active gestation coincident with ovulation in Weddell seals. Thus, the period for embryonic diapause appears to be dramatically shortened, or lost altogether. The absence of any significant diapause causes Weddell seals to have the longest (>10 month) active gestation of any phocid. This would reduce the daily energetic costs of pregnancy, but also extends the time that the developing fetus may be vulnerable to environmental perturbations.

P3-271 SHIDEMANTLE, GI*; FALSO, MJS; BEECHING, SC; PASQUALE, VE; CAMPBELL, ZI; FALSO, PG; Slippery Rock University, PA; *gis1001@sru.edu*

Assessment of Exposure to the Pesticide Imidacloprid on Amphibian Development

Amphibian populations worldwide are declining at accelerating rates. Due to their exploitation of both aquatic and terrestrial habitats, amphibians are greatly affected by chemical changes in their environment and are therefore known to be indicators of ecological conditions. One of the many changes that have been made to the landscape in recent decades has been the use of agricultural pesticides. One class of systemic insecticides, the neonicotinoids, has garnered popularity in the last twenty years and has been found as a contaminant in both ground and surface waters. This research project examined how imidacloprid, the most widely used neonicotinoid insecticide, affects the development of larval frogs as they transition from tadpoles to adults. We exposed the larvae of *Xenopus laevis* (African clawed frog) to four different environmentally relevant concentrations of imidacloprid. The influence of imidacloprid exposure on development was evaluated based on timing of metamorphosis, length, weight and hindlimb length at metamorphosis, and toxicity. By analyzing how imidacloprid exposure impacts this amphibian throughout metamorphosis, we can begin to explore potential consequences of imidacloprid use to other amphibians and across vertebrate classes.

76-6 SHIELD, S*; PATEL, A; University of Cape Town; *SHLSTA001@myuct.ac.za*

Rapid Gait Termination in Humanoids on Surfaces of Varying Friction

In nature, maneuverability is essential to survival, however, the mechanics of high speed motions such as accelerating, turning and braking are still poorly understood, and have yet to be comparably performed in the field of robotics. Rapid deceleration in particular has received little research attention despite being paramount to the safety of fast animals and robots alike. The ground interactions involved in deceleration are of special interest as they create a difficult trade-off: on the one hand, large braking forces lead to more rapid gait termination, but on the other, they create large destabilizing torques and potentially injury-causing reaction forces in the joints. In this study, extensive, large-scale trajectory optimization of high-speed gait termination in a 12 degree-of-freedom humanoid model is used to gain insight into this trade-off for surfaces of varying friction. These observations are then incorporated into a rapid deceleration template which will be used in future studies to implement the maneuver on a robotic platform.

107-8 SHISHIDO, CM; WOODS, HA; TOBALSKE, BW; LANE, SJ; MORAN, AL*; Univ. of Hawaii, Univ. of Montana; *morana@hawaii.edu*

Thermal Sensitivity of Metabolism and Development Across the Life Cycle of the Giant Antarctic Sea Spider Ammothea glacialis

A paradigm of Antarctic biology is that marine ectotherms exhibit slow growth, low metabolic rates, and extended development, and that these processes are highly sensitive to temperature. We measured the effects of temperature on metabolism and development across the life cycle of *Ammothea glacialis*, an Antarctic sea spider (Pycnogonida). Egg masses, larvae, juveniles, and adults all showed large increases in metabolic oxygen consumption between -1.8°C (ambient) and +4°C. We estimated Q_{10}, an indicator of thermal sensitivity of rate processes, for metabolism at each stage. Q_{10}s were generally higher than the expected biological range of 2-3; stage-specific averages varied between ~4 and >20. Adults and juveniles had higher Q_{10}s than larvae or eggs. Despite the > 4 orders of magnitude in size between our juveniles and adults, we saw no evidence for a change in thermal sensitivity with body size within these two groups. Over the same temperature range, the Q_{10} for larval developmental rate was close to that of larval metabolism, suggesting the thermal sensitivity of these two processes are coupled. For juveniles and adults (but not larvae or egg masses) we also measured metabolic rates over a smaller range of temperature, between -1.8 and +1°C. Here the effects of temperature were even more striking, with average Q_{10}s >50. These results suggest that small changes in temperature could have substantial effects on the timing of life history events, the quality and quantity of offspring, population growth rates, and potentially ecosystem function in the Antarctic benthos. NSF PLR-1341476

105-6 SHYAMAL, S*; DAS, S; MYKLES, DL; DURICA, DS; Univ. of Oklahoma, Colorado State University; *shyamal@ou.edu*

Ecdysteroid Signaling in the Crustacean Molting Gland: A Transcriptomic Approach

The Y-organ (YO) is an endocrine gland responsible for cyclic ecdysteroid biosynthesis, regulating molting. In the crab "*" G. lateralis* "", molt entry can be triggered by: 1) eye-stalk ablation (ESA), leading to loss of molt inhibiting hormone (MIH); 2) multiple leg autotomy (MLA), where limb loss coordinates regeneration with new growth/cuticle deposition. Although mTOR and TGF-Beta signaling pathways have been previously identified in molt cycle progression, other signaling cascades driving the production/inhibition of ecdysteroid biosynthesis are largely unknown. To examine gene expression patterns consequent to molt induction, molt entry was induced by both ESA and MLA and YOs processed for RNA-seq at different temporal intervals. Circulating ecdysteroid titers were determined at the time of tissue collection. For both ESA and MLA datasets, the differential expression pipeline included removal of low counts; normalization of count data using RUV-Seq, and identification of differentially expressed (DE) contigs using edgeR. Following filtering and normalization, 35696 (ESA) and 48590 (MLA) contigs were assembled. These contigs were used to identify 8706 (ESA) and 14791 (MLA) DE contigs at a <0.01 FDR cut-off. BLASTx against the KEGG Ortholog (KO) database using human and 6 insect species resulted a total of 878 (MLA) and 464 (ESA) annotations with KO relevant to 23 (MLA) and 24 (ESA) signal transduction pathways. mRNA levels for the genes representing KEGG signaling pathways, including MAP kinase, mTOR, cAMP and Wnt were identified as significantly enriched at a <0.05 FDR cut-off, implicating a role in regulating molt cycle stage transitions. Identification of pathway differences between the two molt-induction methodologies is in progress. Supported by NSF (IOS-1257732).

104-6 SIBERT, EC; Harvard University; *esibert@fas.harvard.edu*

Rapid diversification of open ocean fish and marine communities following the K/Pg mass extinction

The Cretaceous-Paleogene (K/Pg) mass extinction profoundly disrupted marine ecosystems. However, there is mounting genetic and fossil evidence that marine fishes thrived in the aftermath of the extinction event, diversifying rapidly in the early Paleogene open ocean. Here we use ichthyoliths - microfossil fish teeth - preserved deep-sea sediments from the South Pacific Ocean (DSDP Site 596) to investigate the structure of open ocean fish communities from the Cretaceous to the middle Eocene (72-43 Ma). We find that there were two pulses of elevated origination rate of fish tooth morphotypes during the Paleocene. These pulses, which occurred at 64 Ma and from 60-55 Ma respectively, expanded into distinct regions of tooth morphospace, representing differential responses of fish to the mass extinction event. Dissimilarity analyses of fish tooth assemblages reveal that the Cretaceous, and Eocene had distinct but stable fish community structures, which were linked by a v-shaped trajectory through NMDS-space during the Paleocene. The inflection point of this trajectory occurred between the two pulses of origination in the Paleocene. We then used clustering algorithms to group tooth morphotypes with similar shapes, creating morphotype clusters recognized across time bins, and repeated the dissimilarity analyses. The observed pattern of fish community evolution remains consistent across a wide range of morphotype cluster numbers and clustering algorithms, suggesting that there were fundamental shifts in the composition and structure of fish communities across the K/Pg and during the Paleocene. These results suggest that there were distinct shifts in the role that fish played within the Paleocene marine ecosystem, both individually and as an ecological group, as they diversified in the early Cenozoic.

48-3 SIEBERT, S*; FARRELL, JA; CAZET, J; ABEYKOON, Y; MONROY, R; JULIANO, CE; Univ. of California, Davis, Harvard University, Cambridge; *ssiebert@ucdavis.edu*

Towards a single cell molecular map for Hydra

Hydra tissue is very dynamic, with continuous cell displacement, turnover, and replenishment from three lineage-restricted stem cell populations. Interstitial stem cells give rise to the germline, nerves, gland cells, and nematocytes, while cells of the endodermal and epithelial cell lineages can function as stem cells and give rise to the head and foot epithelia. While these populations have been characterized through morphology, transplantation, cellular cloning, transgenesis, and in situ hybridization, their complete transcriptomes remain undefined, and many important questions remain unanswered. For instance, what is the molecular definition of each of these cell types? Do differentiation intermediates exist for each of these stem cell populations, and what are their specific molecular signatures? How many molecularly distinct cell types are present in an adult polyp? To address these questions, we are determining the single cell transcriptomes of all Hydra cells using a droplet based sequencing approach (Drop-seq). Our data reveals which genes are expressed in cells from all lineages and provide insights into their differentiation trajectories. Our approach promises novel insights into diverse areas, such as stem cell decision making, nervous system evolution, and tissue architecture.

P3-275 SIFUENTES-ROMERO, I; TEZAK, BM; MILTON, SL; WYNEKEN, J*; Florida Atlantic University; *isifuentesromero@fau.edu*

Hydric environmental effects on turtle development and sex ratio

Turtles are sensitive to environmental conditions during embryonic development. Experimental and field studies of different species suggest that moisture influences embryonic development and sex ratios, wetter substrates tend to produce more males, and drier substrates produce more females. In this study, we used *Trachemys scripta elegans* to test the effect of moisture on embryonic development and sex ratios. *T. s. elegans* eggs were incubated under different temperature and moisture regimes. We monitored embryonic development until stage 22 (after sex determination) and, for the first time, we estimated sex ratios using a male specific transcriptional molecular marker, *Sox9*. Among treatments, we found differences in developmental rates, egg mass, and sex ratio. Embryos developed slowly in cooler and wetter sand substrate while water uptake by the eggs was significantly greater on wetter substrates. Developmental differences were due to moisture interaction with temperature where increased water content of the sand resulted in temperatures that were 2-3 ° lower than air temperatures. The coolest and wettest substrates produced 100% males compared to 42% males from the warmest and driest treatment. Further, we found that embryonic growth appears to be more sensitive to temperature at earlier stages of development and to moisture at later stages. This study shows how moisture may change the incubation conditions inside nests by changing the temperature experienced by eggs, which affects development, growth and sex ratios. The results of this study highlight the importance of including moisture conditions when predicting embryo growth and sex ratios and in developing proxies of development.

S11-7 SIGWART, Julia D.; SIGWART, Julia; UC Berkeley, Queen's University Belfast; *j.sigwart@berkeley.edu*

Measuring biodiversity and extinction: can global patterns help the species discovery process?

There are intrinsic mathematical patterns in nature. A Fibonacci sequence describes the arrangements of seeds in a sunflower and the spiral of a *Nautilus* shell. Species are natural units, that populate the world around us, and they are formed from branching phylogenetic processes that also have a mathematical structure. So it follows that should be able develop a set of general principles that describe global patterns of species groups, like genera, or families. Understanding such patterns would lend considerable power to the approach of "taxonomic surrogacy". In environmental assessments, ecology, and palaeontology, it is common to substitute genus-level or family-level identification where definitive species identification is impractical. A more robust assessment of the error introduced by taxonomic surrogacy could also improve comparisons of living diversity (where we can hope to identify everything to species, in theory) to the fossil record (which is intrinsically more data limited). But species and species groups are fundamentally not the same. And some higher taxa are "natural" or monophyletic groups, while others are mixed or paraphyletic melting pots awaiting taxonomic revision. Finally, the use of species group designations are potentially different in living and fossil taxa. All of these issues can be addressed through simulation approaches, *in silico* approximations of both large scale phylogenetic scenarios that underpin the evolution of species groups, but also simulation of an "idealised" taxonomic practice. Clarity and confidence in fundamental patterns for taxonomy based on a robust null model - there are more species in the tropics, species-poor genera are very common, large genera are very rare - can accelerate species discovery. We cannot wait to identify all the species on earth before we assess and anthropogenic damage to biodiversity.

P2-49 SIMPSON, DY*; TELEMECO, R; LANGKILDE, T; SCHWARTZ, TS; Univ. of Auburn, Pennsylvania State University; *dys0004@tigermail.auburn.edu*

Corticosterone response of female fence lizards (Sceloporus undulatus) exposed to high temperatures

In vertebrate stress physiology, concentrations of glucocorticoid hormones such as corticosterone (CORT) are thought to increase when animals are exposed to stressful environments, facilitating an adaptive response to diverse stressors. However, we have limited understanding of how natural stressors, such as high temperature, affect the stress response of reptiles. We wanted to determine the corticosterone response to heat stress in the Eastern fence lizard, *Sceloporus undulatus*. Thirty-eight adult females were exposed to 42 °C for varying lengths of time, up to 3 hours. Plasma concentration of corticosterone was measured using EIA. As expected, plasma CORT concentration was higher in lizards exposed to high temperatures, with values similar to previously-recorded responses to other stressors. However, CORT concentration was not proportional to time spent at high temperature with CORT highly variable and plateauing at ~1h of heat exposure, and remaining high after 1 hour of recovery at room temperature. Additionally, movement to experimental chambers appears to have caused part of the observed elevation in CORT. Our results suggest that high-temperature induces CORT production in *S. undulatus* similar to other stressors, although the downstream consequences for performance or behavior are unclear.

28-5 SINCLAIR, BJ; Western University; *bsincla7@uwo.ca*

Applied comparative physiology: Finding the utility in freezing bugs

Insects thrive in every terrestrial habitat on earth, and are destructive agricultural and forest pests, as well as disease vectors. To some extent, studying these phenomena is the realm of pest-focused applied entomology, but what contributions can we make as comparative physiologists? And will addressing these applied questions help us to learn more about how insects work? I will present case studies of applied insect thermal biology, including the emerald ash borer, Asian long horn beetle, Western bean cutworm, and spotted-wing drosophila, using them to illustrate the role of comparative physiology in addressing applied questions. In particular, I will discuss the challenges and opportunities of this applied work, and provide a critical assessment of whether our work has actually yielded benefits (and what we need to do in future to improve knowledge acquisition, transfer, and application). I intend this talk to be of interest to both early career and established investigators hoping to broaden their research portfolio.

88-5 SINGH, AL*; GONZALES, LA; PALUH, DJ; BLACKBURN, DC; Florida Museum of Natural History; *snakesalot@gmail.com*
Variation in the Bony Labyrinth (Inner Ear) of Anurans
The semicircular canals of the inner ear sense positional information of the body and angular acceleration of the head during movement. In birds and mammals with agile and spatially complex movements, differences in canal shape, more specifically canal radius of curvature, are thought to enhance sensitivity to these behaviors. However, it is not understood whether these supposed functional changes in canal radius of curvature in mammals are broadly applicable across vertebrates, or if morphological responses to movement have evolved independently. Documentation of inner ear variation in caecilians and fossorial snakes indicates that both groups may have adopted novel morphological traits thought to enhance sensitivity to movement below ground. We present a survey of the morphological diversity of the semicircular canals of frogs across all extant families and investigate the influence of allometry, ecology, and phylogeny on canal morphology using 3-D geometric morphometrics and phylogenetic comparative methods. Inner ear endocasts were generated from high-resolution micro-computed tomography data, and we document substantial variation in the size and shape of the semicircular canals across species. A multivariate regression between shape and centroid size exhibited significant allometry, indicating there is a strong size-shape relationship in the inner-ear of anurans. Surprisingly, ecology and clade membership had an overall much weaker influence on semicircular canal shape. We lastly quantified the inner ear morphology of several extinct anurans, which were compared to modern taxa to estimate ecological and phylogenetic affinities.

P3-235 SINGH, S.*; GLASS, J.; STAHLSCHMIDT, Z.R.; Univ. of the Pacific; *s_singh40@u.pacific.edu*
Dry dilemma: How does water availability influence dispersal capability?
When water availability is highly variable, terrestrial animals may struggle to maintain water balance. If water becomes limited, animals may disperse to higher quality environments where water is more abundant. However, dispersal itself may be dependent on adequate water availability because locomotor muscles require high water concentration to function properly. *Therefore, does water limitation constrain or promote the maintenance of musculature associated with dispersal?* We investigated this dilemma using the sand field cricket (*Gryllus firmus*), which displays natural variation in investment into dispersal-based flight muscle. Flight capable long-winged morphs of *G. firmus* invest in flight musculature in contrast to flightless short-winged morphs. We placed newly molted adults of both morphs and sexes into two water treatment groups—*ad libitum* water access vs. restricted access to water (water unavailable)—while we controlled temperature and access to dry food. Over five days, we examined how water deprivation affected flight muscle status, gonad mass, body condition, and mortality. Our results will provide new insight into how animals cope with acute periods of dehydration—specifically, the role of water availability in fitness-related traits (e.g., survival and investment into reproduction) and trait-trait interactions (e.g., the tradeoff between flight and fecundity).

45-5 SINGLETON, J. M.*; GARLAND JR., T.; Univ. of California, Riverside; *jsing014@ucr.edu*
Corticosterone, endurance capacity, and home range size in Desert Iguanas (Dipsosaurus dorsalis)
Baseline circulating corticosterone impacts a variety of traits related to locomotor behavior, including glucose mobilization, skeletal muscle function, and probably motivation for activity. Variations in circulating corticosterone levels have likely implications for both individuals and populations, yet the ultimate reason for this variation is unclear. We attempted to manipulate the corticosterone levels of free-living Desert Iguanas (*Dipsosaurus dorsalis*) as part of a series of studies exploring the relationships between baseline corticosterone, endurance, and home range size. Previous observational work on this population has shown a significant positive correlation between endurance capacity and home range size. For the present experiment, 40 desert iguanas received abdominal corticosterone or saline implants in April 2017 and were released back into the population at point of capture. Endurance capacity was measured twice during temporary (< 1 day) captivity. Individual locations were recorded May-July (via visual recognition) for home range evaluation. First endurance measurements occurred an average of 32 days ± 8 after surgery (SD; range = 17-58 days); mean endurance in the first trial was 7.16 min ± 4.8. Second endurance measurements were taken an average of 44 days ± 14 after surgery (SD; range = 24-73). Mean second endurance trial was 9.11 min ± 7.26. No significant effect of implant type was found for either first ($n = 29$; $p > 0.5$) or second ($n = 30$; $p > 0.1$) endurance. Mean home range size was 485 m^2 ± 282 (SD; range = 90-1,057) and lizards with corticosterone implants tended to have larger home ranges ($N = 22$; $p < 0.1$). Forthcoming results will provide hormone levels as context and will incorporate data on relevant ecological factors and estimates of reproductive success.

56-1 SIPLEY, BN*; BULLARD, SA; HALANYCH, KM; Auburn University, Alabama; *breanna.sipley@gmail.com*
The evolution of blood parasitism in trematodes: What's VAP (venom allergen-like protein) got to do with it?
Genes involved in evading or coping with the host immune response underlie the genetic basis of parasitism. Understanding the evolution of genes related to blood parasitism in flatworms is of particular importance, as schistosomes (Trematoda: Schistosomatidae: *Schistosoma spp.*) infect 240 million people in ~78 countries, ranking as the second most devastating parasitic disease in the world. Of interest are the venom allergen-like proteins (VAPs), which are released by trematodes during infection and related to host immunomodulation. Chalmers and colleagues originally described 28 VAPs of 2 main groups consistent with phylogenetic clustering from transcripts of *Schistosoma mansoni*. In 2012, Chalmers and Hoffmann suggested that Group 2 VAPs are structurally and functionally conserved; whereas, Group 1 VAPs are restricted to class-specific clades and highly divergent structurally and functionally. Parasitic Group 1 VAPs may be under positive selection if divergence is driven by host-parasite interactions. Here, we expand our understanding of parasitic flatworm VAPs by including 21 new transcriptomes from non-schistosome blood flukes and 26 transcriptomes from public databases representing each parasitic flatworm class as well as free-living flatworms. We identified complete protein sequences for 578 new VAPs and recovered the phylogenetic clustering observed by Chalmers and Hoffmann, including class-specific clades within Group 1 VAPs. We also test whether these VAPs are under selection. This study is of medical relevance as it should help elucidate VAP residues important in mediating blood fluke host specificity and pathogenicity. Moreover, understanding gene family evolution and patterns of selection in genes involved in host-parasite interactions in flatworms is an important step in understanding the origin and evolution of parasitism more broadly.

105-4 SIRMAN, A/E*; KUCERA, A/C; VANGORDER-BRAID, J/T; LENDVAI, A/Z; HEIDINGER, B/J; North Dakota State University, University of Debrecen; *aubrey.sirman@ndsu.edu*

Does IGF-1 influence growth and cellular aging in house sparrows (Passer domesticus)?

Correlational and experimental studies have demonstrated both within and across taxa that investment in growth comes at a cost to longevity. Despite this, little is known about the physiological mechanisms that underlie this tradeoff. One mechanism that may be important in this regard is insulin-like growth factor-1 (IGF-1). IGF-1 is essential for post-natal growth and development and has been linked with longevity across species. One mechanism by which IGF-1 might impact cellular aging is through its effects on telomere dynamics. To test this, we manipulated circulating IGF-1 in house sparrow (*Passer domesticus*) nestlings during the post-natal growth period in the summer of 2016 and 2017. Nests were assigned to one of three treatment groups: control, experimental, and non-handled control. Experimental nests were injected with a physiologically relevant does of recombinant-human IGF-1 in a carrier matrix from days 3-10 post-hatch. Control nests were injected with only the carrier matrix. We collected blood samples at day 3 and day 10 to quantify telomere length and loss and IGF-1 concentrations. Growth measurements were collected every 3 days until day 10 in control and experimental nestlings. Non-handled controls were only sampled at day 2 and 10 post-hatch. We predicted nestlings injected with IGF-1 would exhibit faster growth, higher IGF-1 concentrations, and greater telomere loss compared to control and non-handled control nestlings. Results will be discussed within the context of life-history theory.

27-6 SLADE, JWG*; WATSON, MJ; KELLY, TR; BERNARDS, MA; GARNER, SG; MACDOUGALL-SHACKLETON, EA; Western University; *jslade23@uwo.ca*

MHC-Mediated Mate Choice and Preen Oil as a Chemical Signal of MHC Similarity in Song Sparrows (Melospiza melodia)

Sexual selection theory has recently expanded our understanding of genetic quality to consider not only additive genetic effects on fitness but also non-additive genetic effects. In jawed vertebrates, a candidate gene family at which both additive and non-additive genetic effects on fitness has been demonstrated is the major histocompatibility complex (MHC). MHC genotype determines the range of pathogens to which an individual can respond, and thus, parasite-mediated selection at MHC often favors particular combinations of alleles (for example, heterozygote advantage). Provided that individuals are capable of assessing the MHC genotypes of potential mates, selection may thus favor non-random mating at MHC. We explored whether chemical cues in the preen oil of free-living song sparrows (*Melospiza melodia*) might convey information regarding MHC class II β genotype. Pairwise similarity in preen oil chemical composition predicted similarity at MHC, indicating a potential route for MHC signaling in songbirds. To investigate the potential for MHC-mediated mate choice, we compared MHC similarity of socially mated pairs of free-living song sparrows to random expectations. Contrary to our prediction of MHC-disassortative mating, social pairs were more similar at MHC than expected by chance. MHC-assortative mating in our system may reflect outbreeding avoidance or the maintenance of co-adapted gene complexes at immune or other loci. Collectively, our findings imply that song sparrows may use chemical cues to assess MHC similarity, but that such cues are used to achieve assortative, rather than disassortative, pairing.

118-4 SLEBODA, DA*; ROBERTS, TJ; Brown University; *david_sleboda@brown.edu*

Diversity in connective tissue morphology across vertebrate muscle

Mammalian skeletal muscle contains three morphologically and functionally distinct layers of intramuscular connective tissue: the endomysium, perimysium, and epimysium. This structural arrangement is assumed to be ubiquitous across the animal kingdom; however, detailed morphological studies of connective tissue have been carried out in only a handful of species outside of Mammalia. We used classic muscle decellurization and scanning electron microscope techniques to visualize the morphology of connective tissues in muscles sampled from a range of vertebrates. We tested the hypothesis that a distinct endomysium, perimysium, and epimysium could be identified in all samples. Frog, turkey, rat, and alligator muscle displayed morphologically distinct layers of endomysial, perimysial, and epimysial connective tissue consistent with those described in the literature. Carp muscle was also visualized and displayed a clear endomysium and epimysium, but a distinct perimysium dividing muscles into fascicles was not apparent. Qualitative differences in the density and arrangement of the endomysium and perimysium were apparent across species. These results reveal a greater diversity in connective tissue structure across vertebrate muscle than has previously been described, and suggest that models of connective tissue developed from studies of mammalian muscle may not necessarily be applicable to all species.
Supported by NIH grant AR055295.

P2-196 SMILEY, A*; ZHONG, K; DUDLEY, R; University of California, Berkeley; Department of Integrative Biology; Museum of Vertebrate Zoology, University of California, Berkeley, University of California, Berkeley; Department of Integrative Biology; *ashley.smiley@berkeley.edu*

Comparative Forward Flight Performance in Four Species of Colombian Hummingbirds

Hummingbirds exhibit a wide range of feeding strategies, flight behavior, and competitive capacity in the wild, along with substantial variation in diverse features of wing and body morphology that will influence flight performance. Here, we examine the effect of body size in forward flight kinematics among different species of Colombian hummingbirds. We examined flight speeds and accelerations during startle flight for individual hummingbirds flying horizontally through a 3 m long tunnel. Using three GoPro cameras, we filmed 371 flight trajectories for four species of hummingbirds: *Amazilia cyanifrons, A. tzacatl, Anthracothorax nigricollis*, and *Colibri coruscans*, with average masses of 5.0 g, 5.3 g, 8.0 g, and 7.9 g, respectively. Additionally, we collected data for wing length, wing area, tail area, and bill length from each individual. Maximal velocity in forward flight is theoretically predicted to exhibit a slight positive allometry, in proportion to the square root of wing loading, whereas maximal acceleration should decline with body mass. We describe here variation among the differently sized species in maximal velocity and acceleration, and discuss potential implications of these allometries in forward flight performance for behavioral outcomes of competitive interactions, foraging, and mating.

P2-96 SMIRNOFF, DS*; GOSLINER, TM; California Academy of Sciences; *dsmirnoff@calacademy.org*

First Molecular Phylogeny of the Nudibranch Family Goniodorididae with an Examination of the Monophyly of Its Main Genera

Nudibranchs are a group of shell-less, marine gastropod molluscs, with over 2,300 named species. The presence of many pseudocryptic and cryptic species often complicates our understanding of true patterns of diversity. For the nudibranch family Goniodorididae, there has been no comprehensive phylogenetic analysis using molecular data. This study investigates the molecular phylogenetics of this family's four major genera: *Goniodoridella*, *Goniodoris*, *Okenia* and *Trapania*. Some morphological phylogenies have been proposed for *Okenia* and *Trapania*, and these results provide an opportunity to test the monophyly of these groups and look for hidden diversity. We used a three gene approach with the molecular markers COI, 16S, and H3, each of which have been shown to be successful in identifying phylogenetic relationships between and within nudibranch genera within a single family. The results clearly demonstrate the uniqueness of many of the lineages that were suspected to represent new species, as well as previously undetected diversity of psuedocryptic species. Preliminary results also support the monophyly of each of the genera studied thus far. The molecular phylogeny confirms the result from morphological data that *Hopkinsia rosacea* must be maintained as a junior synonym to *Okenia* in order to conserve the monophyly of *Okenia*. Within the genus *Trapania*, there is strong support for biogeographically based clades within the Indo-Pacific, Eastern Pacific, and Atlantic; however, these biogeographical patterns are not as clearly represented within *Okenia*. Our results will help elucidate fundamental evolutionary relationships in the family Goniodorididae and lay a foundation for future evolutionary, ecological and conservation biology research.

74-5 SMITH, AM*; PAPALEO, C; REID, CW; BLISS, JM; Ithaca College, NY, Bryant University, Smithfield, RI, Women & Infants Hospital of Rhode Island, Warren Alpert Medical School of Brown University, Providence; *asmith@ithaca.edu*

How Lectins Make Slug Mucus Into a Potent Glue; RNA-Seq Suggests a Central Role for Lectin Variation and Oligomerization

The terrestrial slug *Arion subfuscus* produces a remarkably tough defensive secretion. This dilute gel adheres strongly to anything that touches the slug. The glue is stiff, yet highly extensible. A bioinspired glue based on this secretion was recently developed that greatly exceeds the performance of any currently available medical glues. To analyze the slug glue further, RNA-Seq and tandem mass spectrometry were used to characterize all the proteins in the glue. Most of the proteins were either matrilin-like or lectin-like. The lectin-like proteins are particularly interesting because they make up almost half of the total protein, and they play a central role in glue function. They are relatively small, basic proteins. RNA-Seq found that the lectin-like proteins consist of eleven abundant C-lectins, C1q domain containing proteins, and H-lectins. They shared essential conserved residues, but each typically only had 30-50% sequence identity with any other protein in this group. The ability of these proteins to form hetero-oligomers was tested using native gel electrophoresis and tandem mass spectrometry. Size exclusion chromatography was used to quantify the size of complexes. These experiments found evidence that the C-lectins and C1q-containing proteins form heterotrimers and heterodimers respectively. Each subunit likely has a different binding specificity, making them versatile linking agents.

P1-33 SMITH , C/J*; MIDDLETON , K/M; BAILLEUL, A/M; HOLLIDAY, C/M; University of Missouri, Columbia ; *cjszk5@mail.missouri.edu*

Bending Properties of the Lower Temporal Bar in Ducks and its Significance for Cranial Biomechanics

Few species evolved skulls as derived as ducks and other anseriform birds, which employ rapid, dexterous movements of the palate and jaws to feed. Despite their exceptional behavior and morphology, little is known about the structure and biomechanics of their jaw muscles, cranial joints, and linkages that facilitate cranial kinesis. The lower temporal bar (quadratojugal and jugal) links the quadrate and the upper beak and is flexible, but the structural properties underlying this flexibility remain unclear. We dissected the lower temporal bars from a sample of Mallard ducks. One side was fixed, imaged in microCT, and followed by histological sectioning at three focal areas. The contralateral side was tested in three-point bending following standard protocols to estimate whole element stiffness. We found the lower temporal bar was less mineralized than the quadrate overall, and became less dense rostrally. Second moments of area show that the lower temporal bar is about six times more resistant to bending about the mediolateral axis. Histologically, the lower temporal bar is homogeneously constructed and resembles an avian mineralized tendon instead of cranial intramembranous bone. The Young's moduli of the element are intermediate between mammalian fetal bone and haversian bone. We conclude that the flexibility of the lower temporal bar of ducks results from several changes to the shape and composition of the bone. This suggests birds may employ a diversity of modifications to skeletal tissues to facilitate flexibility in the bones of the feeding apparatus.

90-7 SMITH, GD*; HUDSON, SB; FRENCH, SS; Dixie State University, Utah State University; *geoffrey.smith@dixie.edu*

A Country Lizard Will Survive: Urban and Rural Individuals Respond Differently to Climatic Variation

As humans continue to change the world, the effects of urbanization and climate change will be among the largest drivers of declines and extinctions. Furthermore, the interaction of climate on urban areas could have synergistic effects on individuals and populations. For six years, we have measured physiological parameters and estimated survival in side-blotched lizards in the urban center of Saint George, Utah, and in surrounding rural areas. Throughout the course of this work, droughts and wetter years have affected the reproductive investment, immunocompetence, and survival estimates differently in urban and rural populations. As the American Southwest is projected to grow increasingly hot and arid, these findings might help us predict how animals in urban areas will respond to climate change.

93-5 SMITH, EK*; WOLF, BO; University of New Mexico; *ericsm@unm.edu*

Are there limits to the heat dissipation limit theory? In desert birds, water is the missing ingredient

Speakman and Król (2010a,b) have hypothesized that heat dissipation limits are responsible for constraints on activity rates and energy expenditure in endotherms and developed a model for heat loss in mammals and birds. Interestingly, the clearly stated assumptions of the heat dissipation model require that animals are not heat stressed: that air temperatures (T_{air}) remain below upper critical temperature (T_{uc}), solar radiation is negligible, and internal surfaces do not participate in heat exchange with the environment as "heat is normally conserved in the process of conserving water" (Speakman and Król, 2010a, p. 730). As diurnal endotherms, desert birds are often exposed to intense solar radiation and high T_{air} that leads them to experience environmental temperatures above T_{uc} and normothermic T_b. Although birds typically reduce activity levels and seek shaded microsites during the heat of the day, operative environmental temperatures exceeding T_b result in the evaporation of large quantities of water for heat dissipation. As a consequence, for desert endotherms, during a large part of their annual cycle, the assumption of the HDL model that evaporative water loss is unimportant to heat balance is not valid. Our data on birds indicate that they may dissipate more than two times their metabolic heat loads evaporatively and thus water loss rates may in fact constrain performance and behavior. Therefore, we propose that the HDL model be modified to account for evaporative heat loss in endotherms and in desert birds specifically.

P3-75 SMITH, WA*; GELAF-ROMER, T; RENTERIA, S; THWIN, A; NOONAN, B; ANDERSON, P; COHEN, L; WINSTON, S; ZAMAN, M; EL NAGGAR, K; ROSENGAUS, R; SMITH, Wendy; Northeastern University, Johns Hopkins University, Great Falls College; *w.smith@neu.edu*

Maternal Effects of Aseptic and Septic Injury on Embryonic and Larval Gene Expression in the Tobacco Hornworm, Manduca sexta

Cross-generational effects of physical and pathogenic stress have been demonstrated in several insect groups. Prior studies in our lab have shown that, in the tobacco hornworm, *Manduca sexta*, maternal bacterial exposure increases variability in embryonic size and enhances larval bacterial clearance. The current project further characterizes the effects of maternal septic and aseptic injury on offspring, focusing on gene expression. *M. sexta* females were injected just before adult eclosion with sterile saline or live *Serratia marcescens*. Naïve controls received no treatment. After eclosion and mating with untreated males, embryos were examined for changes in gene expression. Hatching rates and frequencies were also measured. We observed changes in the expression of several immune-related genes in embryos of mothers treated with live bacteria, including prophenoloxidase-activating protease, in comparison to offspring of untreated or saline-treated mothers. In larvae, expression of the same immune-related genes increased in offspring of mothers from all treated groups relative to those from untreated mothers. Despite differences in gene expression, we observed no global alterations in histone acetylation. Future studies will elucidate whether methylation or histone acetylation of specific immune-related genes can help to explain changes in gene expression and immune response. Our results are consistent with maternal effects that enhance offspring immunity in stressful environments. Our thanks to support from NSF (REU Award 1460628), and from Northeastern University (Tier 1 and Undergraduate Research Awards).

88-6 SMOLINSKY, AN*; MIDDLETON, KM; Univ. of Missouri, Columbia; *ansgh2@mail.missouri.edu*

Muscle- and impact-dominated activities differentially affect bone morphology and mineral apposition in young outbred mice

The skeleton can respond to forces encountered over an individual's lifetime by altering bone structure or shape to resist commonly encountered loads, thereby decreasing fracture risk. To explore the effects of ground-reaction (GRF) and muscle forces on the skeleton, we examined the cross-sectional growth and gross morphologies of the femur under varying loading regimes. Four-week-old outbred (ICR) mice were divided into four activity treatment groups, each exposed to a different source of loading for 21 days: downward jumping to increase GRF, swimming to increase muscle loading, wheel running to mimic the combination of muscle and GRF in natural locomotion, and non-exercised controls. Fluorochrome labeling during the last week of treatment allowed bone growth assays. Mid-diaphyseal thin sections of the left femur were examined for cortical growth patterns and mineral apposition rate, and gross shape changes were assessed using 3D landmark analysis of right hind limb micro-CT scans. Histological analysis indicated that, in all groups, mineral apposition occurred most consistently on the posterior-facing endosteal and periosteal surfaces, indicating posterior cortical drift. Additional apposition on other cortical surfaces characterized each experimental loading regime, with the apposition pattern in the running treatment most resembling that of swimming. Mineral apposition rates were also found to differ from controls in all three treatment groups, especially in the lateral sectors of the cross-section, and again the running and swimming groups were most similar. These results reveal the intricate patterns of apposition on both cortical envelopes that lead to changes in geometric properties and gross morphology of bone following exercise.

P3-256 SMOOT, SC*; ZOHDY, S; SCHWARTZ, TS; Auburn University; *scs0051@auburn.edu*

Population genetics of mouse lemurs and their ecto-parasites in Ranomafana National Park

Madagascar is home to very high levels of deforestation having over 90% loss of its original forest cover. Mouse lemurs are the smallest primates in the world and are endemic to Madagascar and live in fragmented and continuous areas of rainforest. The goal of this project was to understand the population structure of the Eastern brown mouse lemur, *Microcebus rufus*, and its specialist ecto-parasite, *Lemurpediculus verruculosus*, in Ranomafana National Park. Extracted DNA from 47 samples of *Microcebus rufus* individuals and ethanol preserved lice from their corresponding hosts were used to estimate population genetic structure and genetic diversity using restriction-site associated DNA sequencing (RADseq). Dual-digest RADseq (3RAD) is a type of RADseq that uses three digestion enzymes that yields thousands to tens of thousands single nucleotide polymorphisms (SNPs) from across the entire genome. We are continuing comparisons and hypothesize increased population structure within *M. rufus* samples across Ranomafana National Park, due to reduced gene flow across existing forest fragments. The lice will also show increased population structure due to the close coevolution relationship between *M. rufus* and its lice. Results from this experiment will help in understanding of the genetic effects of habitat fragmentation and its implications in rainforest conservation.

S10-12 SNELL-ROOD, Emilie C*; KOBIELA, Megan E; University of Minnesota; *emilies@umn.edu*

Potential for adaptation of pollinators to roadside habitats: effects of sodium and heavy metals

Roadsides are a unique anthropogenic habitat. Nitrogen and sodium accumulate due to deposition from exhaust and road salt application, respectively; both nutrients could potentially attract animals, especially herbivores, to roadsides. However, roadside environments may also be toxic, either from very high levels of salt, or from heavy metal accumulation (zinc, cadmium, nickel) from tire and brake pad wear. To what extent might insect pollinators be able to behaviorally adjust or adapt to such conditions along roadsides? This talk will review several ongoing projects relevant to this question. First, surveys of roadside soils, plants and insects are testing how nutrient and heavy metal content varies with traffic volume and urbanization. Second, behavioral experiments are testing whether female butterflies are attracted to or repelled from host plants containing high levels of sodium. Finally, a series of rearing experiments are testing patterns of standing genetic variation in the ability of several species of butterflies to cope with high sodium concentrations in their larval diet. Additional rearing experiments consider responses to heavy metal exposure. To date, results suggest ample variation in performance on a range of salt diets across sibling families, suggesting potential for adaptation to high sodium along roadsides. In addition, exposure to low levels of some heavy metals has little, to sometimes positive (hormetic), responses on performance. Upcoming experiments will consider how nitrogen, sodium, and metals may interact to affect performance of both butterflies and bumblebees. Overall, roadsides serve as an intriguing case study in understanding how animals may adapt to novel, patchy environments that are thought to be ecological traps.

P3-131 SNYDER, RK*; OSPINA-L, AM; WARKENTIN, KM; SNYDER, Rachel; Susquehanna University, Universidad del Quindío, Boston University; *rachelksnyder4@gmail.com*

When Does Flooding Induce Hatching? Behavioral Decisions of Red-Eyed Treefrog Embryos Under Moderate Hypoxia

The arboreal embryos of *Agalychnis callidryas* experience hypoxia when individual eggs or whole clutches fall into ponds. This can slow development or kill embryos too young to hatch, and induces premature hatching once embryos are able to hatch. Nonetheless, hatching early carries costs, and the extent to which flooding constrains metabolism must vary with egg surface-exposure and aquatic oxygen level. We measured oxygen just outside eggs flooded in clutches and singly. Oxygen depletion was faster and more severe when whole clutches were flooded. We examined responses of premature, hatching-competent embryos to a best-case flooding scenario, submerging fully-exposed individual eggs in normoxic water. Embryos began hatching within 20 min of flooding and nearly half hatched within a few hours, but many tolerated a 2-3 day period of submergence and moderate hypoxia before hatching. We continuously monitored behavior of individual embryos for 15 min in air and 75 min after flooding to examine their oxygen-sampling process and decision to delay hatching. At ages 3 and 4-d, movement rate increased over four-fold upon flooding, then returned to pre-flooding levels after about 30 min of submergence. In earlier work, submerging less-exposed eggs in hypoxic water, movement rates peaked at much higher levels and all embryos decided to hatch, on average after 15 min at 3-d and 7 min at 4-d. With moderate hypoxia, oxygen-sampling was less intense but longer, differences between ages were weaker, and many embryos decided not to hatch immediately. *A. callidryas* embryos appear to modulate oxygen-assessment and hatching decisions with flooding context, and ontogenetic changes in the response to flooding are context-dependent.

P3-229 SOCKI, F*; PRICE , SL ; DOERING , G; BURROUGHS , RW ; MOREAU , CS; Ohio Wesleyan University , The Field Museum, University of Chicago; *fmsocki@owu.edu*

Three-dimensional Modeling and Morphometric Analysis of the Elaborate Soldier Heads in Turtle Ants (Cephalotes)

Ants are ideal organisms to study evolutionary patterns due to their species richness, ecological significance, and morphological diversity. Soldiers are a caste that have the sole purpose of defending the colony. The diverse genus *Cephalotes*, also known as turtle ants, is a primary example of extreme morphological adaptation of the caste system. Many species of turtle ant soldiers have evolved heads that they physically use to block the entrances into their colonies. There are a variety of soldier head shapes that have been defined, with four types classified so far. For this study we wanted to quantify the variation in shape of soldier heads across *Cephalotes*, with the ultimate goal of understanding how soldier head shape evolves in *Cephalotes*. We used over 50 specimens of both soldiers and workers from the collections at the Field Museum of Natural History and scanned them using micro computed tomography (microCT) at the University of Chicago PaleoCT facility. Each specimen's scans were then processed, cleaned and reconstructed into a three dimensional model using several programs. The head was separated from the model, and excess body parts that could potentially cause error, such as antenna, were removed from the head. Morphometric analysis was then performed on all soldier heads to assess shape variation. This was performed by placing a thousand points over the entire surface of each ant head, both with three-dimensional and two-dimensional samples. We then measured the difference in the location of the points across our samples through principal component analysis (PCA) to quantify head shape. From here we will use our morphological data and turtle ant phylogeny to investigate trait evolution.

P3-38 SOKOLOV, EP; SOKOLOVA, IM*; Universität Rostock; *inna.sokolova@uni-rostock.de*

Effects of compatible osmolytes on mitochondrial functions of a marine osmoconformer

Salinity is an important environmental factor affecting physiology of marine organisms. Osmoconformers such as marine mollusks maintain metabolic function despite changes of the osmolarity and composition of the cytosol during salinity shifts. Currently, metabolic responses to the salinity-induced changes of the intracellular milieu are not well understood. We studied the effects of osmolarity (450 vs. 900 mOsm) and compatible osmolytes (70-590 mM of taurine or betaine) on isolated gill mitochondria of a marine osmoconformer, the Pacific oyster *Crassostrea gigas*. Physiological concentrations of taurine enhanced mitochondrial ATP synthesis (OXPHOS) and electron transport system (ETS) capacity, increased mitochondrial coupling and stimulated the forward flux through the Complex I potentially alleviating production of the reactive oxygen species. In contrast, betaine proportionally increased the rates of the mitochondrial proton leak and OXPHOS flux with no net effect on the mitochondrial coupling and suppressed the activity of cytochrome c oxidase in oyster mitochondria. However, the effective concentration of betaine (590 mM) was higher than typically found in bivalves under the physiological conditions in vivo. Our findings indicate that taurine may support the mitochondrial bioenergetics during hyperosmotic stress in oysters. Compatibility of taurine with the metabolic functions and its beneficial effects on mitochondria may have contributed to its broad distribution as an osmolyte in marine osmoconformers.

S9-2 SOKOLOVA, I.M.*; SOKOLOV, E.P.; IVANINA, A.V.; Universität Rostock, University of North Carolina at Charlotte; *inna.sokolova@uni-rostock.de*

Mitochondria from Hell: The Role of Mitochondrial Mechanisms In Stress Tolerance Of Animal Extremophiles

Mitochondria play a central role in energy provisioning, redox and Ca^{2+} homeostasis, signaling and life-death decisions. Animal mitochondria are extremely sensitive to the direct and indirect effects of environmental stressors, and mitochondrial injury and dysfunction are common causes of pathology caused by hypoxia, temperature stress, toxins or metal overload. Mitochondrial sensitivity to external disturbances raises an important and as yet unresolved question: how is the mitochondrial function and integrity maintained in animals adapted to extreme environments where the ambient conditions fluctuate strongly, frequently and unpredictably within the life cycle of an individual? Intertidal organisms represent excellent models to study the mitochondrial adaptations to stress as they inhabit one of the most physically challenging environments on Earth characterized by strong fluctuations in temperature, salinity, oxygen concentration, pH, desiccation and hydrodynamic forces. We will present the current state of knowledge on the mitochondrial responses to environmental stressors (including intermittent hypoxia, temperature, salinity, pH and toxic metals) in marine intertidal mollusks, identify the mitochondrial mechanisms that may set limit to the organism's stress tolerance and discuss the potential future research directions to pinpoint the sensitive mitochondrial targets and adaptive mechanisms to extreme stress. Investigations of the mitochondrial adaptations of animal extremophiles can shed important light on the evolution of metabolism in extreme environments and help identify potential targets for future therapies to protect sensitive mammalian tissues from stress-induced injuries (e.g. during ischemia-reperfusion or metal overload).

P2-241 SOLLA, A.K.*; O'ROURKE, C.F; RENN, S.C.P.; Reed College; *sollaau@reed.edu*

Role of Male Dominance Fights on Female Mate Choice in a Cichlid Fish

Astatotilapia burtoni, an African Rift Lake cichlid, are a model organism for understanding social behavior in the lab. Much work has been done in the past on examining the role of male-male dominance interactions, and how other males use observations of these fights to determine social standing through transitive inference. It has been hypothesized that female *A. burtoni* also observe male dominance interactions, so as to decide which male to spawn with. We investigated whether female *A. burtoni* were observing male fights, and changing their patterns of association based on the outcome of the dominance interaction. Females were allowed to choose between two size-matched males before the fight, observed the two males fight, and were allowed to choose between the males again after the fight. With preliminary results, the visual components of the male fight appear to influence female choice, but do not fully explain female mate choice in *A. burtoni*. This suggests that more work may need to be done on exploring non-visual sensory systems in *A. burtoni*, and how those systems contribute to female mate choice.

P1-44 SOLOMON, JC*; KONOW, N; SOLOMON, JACOB; University of Massachusetts, Lowell; *jacob_solomon@student.uml.edu*

Elastic Element Action during Food Processing in Axolotls

Studies of limb muscles often conclude that stretch and recoil of series elastic elements act to decouple joint movement from contraction of muscle. However, this phenomenon, often associated with a functional increase in movement speed, has rarely been documented for feeding systems. In lungfishes and salamanders, the muscles responsible for jaw depression and adduction attach to the mandible on opposite sides of the jaw joint, and may potentially antagonize each other as they control jaw movement. Previous electromyography studies have revealed temporal decoupling between activation of jaw muscles and their expected action upon the mandible in both taxa. Such delays suggest the presence of a compliant element within the system. Recently developed biplanar high-speed x-ray approaches now permit analyses of distinct contractile and elastic components within this system. We used fluoromicrometry and XROMM to measure the relationship between changes in length of active muscle fascicles and whole muscle-tendon units (MTUs)with respect to chewing gape cycles in Axolotls. We predicted finding evidence of decoupling of jaw movement from contraction of muscle fibers, either as fiber shortening or isometry during MTU lengthening (or isometry). In support of this prediction, our data showed durations of muscle fiber shortening averaging 0.27 ± 0.15s during MTU lengthening or isometry, suggesting the action of a series elastic element. Jaw closing speeds averaged 7.8 ± 1.6 cm s^{-1}, or up to 8.4 jaw adductor resting lengths s^{-1} (a conservative estimate, calculated using the length of the MTU as reference length). Such speeds are in the upper range of what sarcomeres can achieve and thus suggest that elastic recoil enables faster jaw movements, which in turn may help minimize risks of losing struggling prey.

P1-34 SOMMERFELD, N*; HOLZMAN, R; Tel-Aviv University and The Inter-University Institute, Eilat; *noamsommer@gmail.com*

What determines capture success of copepods by fish larvae?

Larval fishes experience extreme mortality rates, with 99% of a cohort perishing within days after starting to actively feed. The survival of these larvae is strongly dependent on their ability to capture prey. Most larval fish capture prey by rapidly expanding their mouth cavity, generating a "suction flow" that draws the prey into their mouth. Unlike adult fishes, larvae live in a hydrodynamic environment characterized by low Reynolds numbers (Re), which impedes their ability to capture prey. Experiments with non-escaping prey (Rotifers) shows the larvae have to execute high-effort strikes in order to "escape" the low Re regime and feed successfully, and that this ability is facilitated by ontogenetic growth. However, how these results extend to the larvae's ability to feed on natural prey that does escape (e.g. copepods and copepodites) in response to hydrodynamic cues is unclear. We filmed *Sparus aurata* larvae (9-28 days post hatching) feeding on natural prey assemblages using 3D high-speed, high resolution camera system. This system enabled 3D tracking of landmarks on the prey and predator and calculation of their body movements and mouth kinematics. We observed four types of interactions where: (1) prey successfully escaped before the larvae opened its mouth, (2) prey successfully escaped after the larvae opened its mouth (3) prey was captured despite trying to escape, and (4) prey was captured without trying to escape. We used discriminant function analysis to understand which predator/prey kinematics best classified the interaction type, and discuss the results with respect to larval ontogeny.

9-2 SOMO, DA*; MORRISON, PR; RICHARDS, JG; The University of British Columbia; *somo@zoology.ubc.ca*

Differential Temperature Sensitivity of Oxygen Uptake in Hypoxia in Marine Fishes

Temperature increases and hypoxia are two key factors associated with global climate change already affecting the distribution and abundance of marine organisms. In an effort to predict climate-changed induced shifts in habitat suitability, models have been developed based on the temperature sensitivity of the critical oxygen tension (P_{crit}) for minimum rate of oxygen uptake (Ṁo_{2min}). Few studies have used a robust comparative approach to understand the physiological significance of variability in the temperature sensitivity of P_{crit}. We measured the impacts of acute temperature increase on P_{crit} in nine species of marine sculpin which vary in hypoxia tolerance to characterize the intrinsic temperature sensitivity of this trait. We also measured critical thermal maximum (CT_{max}) to assess relationships between P_{crit} and CT_{max}. Though P_{crit} and Ṁo_{2min} increased significantly with temperature in all species, sculpins fall into two groups: those with nearly equal Q_{10} values for these two traits, and those with significantly lower Q_{10} values for P_{crit} *vs.* Ṁo_{2min}. The Q_{10} analysis suggests that some sculpins acutely increase their capacity for oxygen uptake in hypoxia at higher temperatures despite large increases in Ṁo_{2min}. Preliminary measurements suggest that the temperature sensitivities of hemoglobin-O_2 binding affinity are similar to temperature sensitivities of P_{crit}, potentially implicating a role for differential temperature effects on hemoglobin-O_2 binding in modulating whole-animal oxygen uptake in hypoxia at elevated temperature.

48-6 SONG, H.; JACOBS, D/K*; Department of Ecology and Evolutionary Biology, University of California, Los Angeles; *djacobs@ucla.edu*

The T-box gene family and their differential expression pattern in the jellyfish Aurelia

Members of the T-box (Tbx) gene family, founded by Brachyury class genes and well known for critical roles in gastrulation and notochord development, also play important roles in tissue and neural development including the development of heart and limbs in many vertebrate and invertebrate species. We employed genome and transcriptome information to better understand the role these genes play in the complex "multistage" development of medusozoan Cnidaria which involves dramatic metamorphosis from planula to polyp and and polyp to medusa. We identified 8 Tbx genes in *Aurelia sp.1*, including Brachyury-a, Brachyury-b, Tbx2/3a, Tbx2/3b, Tbx4/5a, Tbx4/5b, Tbx20 and Tbx1/10. Our results suggested evolution of a separate medusozoan specific Brachyury homologue, and additional cnidarian specific Tbx duplication. RNA-seq data revealed the differential expression pattern of 7 Tbx genes across planula, polyp, strobila, ephyra and juvenile life history stages of *Aurelia*. Two Brachyury and two Tbx2/3 are highly expressed in planula stage, potentially relating to planula neural development and apical organ formation. Tbx1/10 and two Tbx4/5 are highly expressed during strobilation, the initial phase of medusa formation, when rhopalial neurons and muscle cells differentiate from their progenitor cells and the rhythmic bell-contraction system develops. In chordates, Tbx1/10 is crucial for muscle differentiation and Tbx4/5 controls cardiac conduction system patterning including the development of the beat generating node. We hypothesize that these genes in *Aurelia* may similarly regulate the node driven contraction and neuromuscular differentiation in the development of the swimming ephyra/medusa stage initiated during strobilation.

68-7 SORTE, CJB*; BERNATCHEZ, G; PANDORI, LLM; SILBIGER, NJ; WALLINGFORD, PD; Univ. of California, Irvine, Univ. of California, Irvine; Cal. State Univ., Northridge; *csorte@uci.edu*

Warming Tolerances and Predicted Distributional Shifts Differ by Species in a Diverse Intertidal Mussel Guild

Climate change is driving shifts in species distributions, and warming is accelerating over the 21st century. Impacts on individual species can escalate up to community and ecosystem levels, particularly when they involve strong interactors. In rocky shore systems, mussels are dominant foundation species that provide habitat and support diverse assemblages of associated species. The mussel guild in New Zealand is particularly diverse with four co-occurring species. By integrating comparative ecophysiology and population ecology approaches, we found that temperature appears to limit upper intertidal extents across low- and mid-intertidal species. Specifically, (i) lethal thermal limits coincided with temperatures experienced at upper tide-height limits, (ii) species with higher thermal tolerances occurred higher on the shore, and (iii) lethal tolerances were higher at a warmer site than cooler site. We uncovered differential vulnerability of species in the New Zealand mussel guild to climate warming. By year 2100, two species (*Perna canaliculus* and *Aulacomya maoriana*) are likely to experience temperatures exceeding their LT50 (temperature lethal to 50% of individuals) 4 to 24 times more often at their current maximum tide height. In contrast, *Mytilus galloprovincialis* is much less likely to experience temperatures exceeding its LT50 based on climate projections. These results suggest that intertidal ranges of *Perna* and *Aulacomya* are likely to contract, increasing dominance of the more tolerant *Mytilus* and decreasing overall habitat availability for associated organisms.

16-3 SOUTHER, JL*; GUNDERSON, AR; PAGANINI, AW; TSUKIMURA, B; STILLMAN, JH; San Francisco State University, Fresno State University; *Jennifer.L.Souther@gmail.com*

Transducing abiotic stress to biotic stress in the porcelain crab Petrolisthes cinctipes

Climate change is expected to cause organisms to shift their distributions and there is great interest in understanding when and where they will move. The porcelain crab *Petrolisthes cinctipes* is found under rocks in the mid-intertidal zone on North America's Pacific coast where temperatures reach the crabs' thermal limit. The low intertidal zone is a cooler habitat but moving there would likely result in their increased density. We hypothesized that elevated temperatures will cause *P. cinctipes* to move, increasing their density and aggressive interactions. We tested this with experimental mesocosms that replicate an elevation gradient with automated temperatures and tides. Temperatures used were recorded under a rock at the collection site and modified to not exceed the critical thermal limit of the crabs. Tides were programmed to mimic the tides experienced during that same week. There were 3 treatments: tidal water variation with low tide warming, tidal water variation with no low tide warming, and constant immersion. Experiments lasted one week after which crabs were surveyed for location and injury/mortality. We found that crabs in enclosures with warming experienced more injuries (proportion of crabs injured = 0.17 ± 0.02 vs 0.08 ± 0.02, $p=0.003$) but there was no difference for crab locations (proportion of crabs in high intertidal zone = 0.18 ± 0.05 vs 0.11 ± 0.04, $p=0.32$). Increased injury under heat stress suggests that there may be indirect negative effects of temperature stress that result from altered behavioral interactions. Understanding indirect effects such as these may help predict how and when species distributions will shift in the future.

P2-215 SOWARDS, SH*; CIERI, RL; FARMER, CG; University of Utah, Salt Lake City; *steffan.hs.13@gmail.com*
Computational fluid dynamics modeling of pulmonary airflow patterns in a Python regius
The phylogenetic distribution and mechanisms underpinning unidirectional pulmonary airflow, in which gases pass through a portion of the lung in an identical direction during both inspiration and expiration, are poorly understood. Until recently, it was thought this pattern of flow required unique features of the avian respiratory system. Recent findings, however, show this type of airflow occurs in crocodilians and some squamates, which exhibit a whole gamut of respiratory structures distinct from those of the avian lung. In order to further elucidate the phyletic distribution of this pattern of flow, and to elucidate mechanisms and anatomy that produce aerodynamic valves among diapsids, a mathematical model of the pulmonary system of *Python regius* was constructed using computed tomography (CT) and by segmenting regions of interest of these CT data. This model served as the domain for a computational fluid dynamics simulation of pulmonary airflow. The Pythonidae pulmonary system is characterized by a proximal faveolar region where gas exchange occurs, as well as a distal sac-like region that is hypothesized to serve as an air reservoir and may be responsible for the bulk of respiratory airflow. Simulated pulmonary airflow in a static model exhibits cranial flow during both inspiration and expiration along the central and dorsal portion of the right faveolar lung. A dynamic model, where moving walls serve as the boundary conditions and drive airflow in and out of the lung, may provide additional information about flow during all phases of ventilation. An understanding of the type of airflow observed in the Pythonidae respiratory system and the structural features contributing to unidirectional airflow has implications for the understanding of the evolution of the vertebrate respiratory system as well the optimization of future engineered prosthetic pulmonary solutions.

P1-11 SPAIN, D.D.*; MENDOZA, V.M.; CHAVEZ, B.A.; Dominican University of California; *diara.spain@dominican.edu*
Using a Case Study to Teach Ocean Acidification
Case studies can be used to guide student learning in small groups and as a class through reading, analysis, and discussion. We developed an ocean acidification case study for students in general science classes. The case topics included ocean chemistry, historical and recent data on carbon dioxide emissions, and shell damage in a marine snail. Specifically, we designed the case study questions at varying levels of cognitive learning ranging from knowledge, comprehension, application, up to analysis. Two weeks later, students were asked to complete a short survey about the content of the case study and their opinion on its effectiveness. Overall, the survey results were positive. For example, 100% of students were able to correctly answer that the Keeling Curve shows increased carbon dioxide emissions. This question was at the level of knowledge and comprehension. Additionally, when it came to understanding ocean acidification, 87% of the students rated the case study as very or extremely effective. Our results indicated that this case study was successful in educating students on ocean acidification. Next, we plan to use the case and administer the survey for another class in the fall to extend these results.

118-3 SPAINHOWER, KB*; METZ, AK; BARKETT, EM; YUSUF, AR; BUTCHER, MT; Youngstown State Univ.; *kspainhower@student.ysu.edu*
Hanging Out: Fiber Type Distribution and Energy Metabolism in Sloth Forelimb Muscles
Sloths are canopy-dwelling inhabitants of American neotropical rainforests that exhibit suspensory locomotion and posture. These abilities involve hanging below branch from hook-like feet, and although they require great strength and endurance, the skeletal muscle mass of sloths is reduced, thus requiring modifications to muscle architecture for large joint torque. We hypothesized that intrinsic muscle properties also are modified for fatigue resistance by homogeneous expression of slow myosin heavy chain (MHC) fibers that rely on aerobic metabolism for sustained contraction. This hypothesis was tested by determining MHC fiber type distribution and energy metabolism in the forelimb muscles of two-toed (*C. hoffmanni*, *N*=4) and three-toed (*B. variegatus*, *N*=5) sloths using protein gel electrophoresis, immunohistochemistry, and enzyme activity assays. A primary expression of the slow MHC-1 isoform as well as moderate expression of fast MHC-2A fibers and few hybrid MHC-1/2A fibers are found in both species. MHC-1 fibers are larger in cross-sectional area (CSA) than MHC-2A fibers and comprise the greatest %CSA in each muscle sampled. The enzyme assays show elevated activity for anaerobic enzymes compared to low activity for aerobic markers. Notably, enzyme activity and MHC fiber type are uncorrelated. The lack of support for the predicted fiber type properties suggests that sloth limb muscles have appreciable tolerance for lactate accumulation, but may rely more heavily on rapid ATP re-synthesis pathways. Still, the intrinsic properties observed match well with their locomotor requirements, and these modifications may have further evolved in unison with low metabolism and body temperature, and slow movement patterns as means to conserve energy.

94-3 SPARKMAN, A*; CHISM, K; BRONIKOWSKI, A; BRUMMETT, L; COMBRINK, L; DAVIS, C; HOLDEN, K; KABEY, N; MILLER, D; Westmont College, Iowa State University, Pennsylvania State University, Iowa State University; *sparkman@westmont.edu*
Differences in Developmental Phenology and Maternal Egg Provisioning in Two Sympatric Viviparous Snakes
Major aspects of embryonic development, such as the rate and timing of development, and maternal-fetal interactions can be critical features of early-life fitness and may impact population trends. Development is known to be affected by a combination of factors such as photoperiod, temperature, humidity, and reproductive mode. How environmental and phylogenetic factors interact to regulate development in the wild, however, can be challenging information to obtain. Information on development in wild squamate reptiles is particularly limited, due to the secretive habits of many in this clade. Nevertheless, the repeated evolution of viviparity and consequent diversity of reproductive mode make squamates a particularly valuable subject of study. We used field-portable ultrasonography to investigate embryonic development in two sympatric species of garter snake, *Thamnophis sirtalis* and *T. elegans* living in meadows in the Sierra Nevada mountains. Both species are viviparous, primarily lecithotrophic, occupy similar ecological niches and experience the same annual environmental conditions. We found that T. sirtalis embryos were more developmentally advanced than *T.elegans* embryos during June of three consecutive years. We also found that eggs increased in volume more substantially across developmental stages in *T. elegans* than in *T. sirtalis*, indicating differences in the degree to which embryos received additional maternal provisioning via placental transfer. These findings demonstrate interspecific differences in developmental phenology within the same environmental context, and deepen our understanding of differences in maternal-fetal interactions even in closely-related viviparous species.

7-4 SPEISER, DI*; CHAPPELL, DR; KINGSTON, ACN;
University of South Carolina; *speiser@mailbox.sc.edu*
Expression of G-proteins in the eyes and parietovisceral ganglion of the bay scallop Argopecten irradians
A surprising diversity of invertebrates have many image-forming eyes scattered across their bodies. Recent efforts have characterized the structure and function of individual eyes from these distributed visual systems, but less progress has been made towards characterizing the neural structures associated with them. Scallops, for example, have a distributed visual system that includes dozens of image-forming eyes with mirror-based optics. The optic nerves that exit these eyes travel to the lateral lobes of the parietovisceral ganglion (PVG), but we have yet to learn how scallops may process spatial information within this brain-like organ. To learn more about the scallop visual system by identifying sensory receptors and chemical synapses, we studied the expression of four G protein α subunits (Gαi, Gαo, Gαq, and Gαs) in the eyes and PVG of the bay scallop *Argopecten irradians*. In the eyes, we noted expression of Gαo by the ciliary photoreceptors of the distal retina, expression of Gαq by the rhabdomeric photoreceptors of the proximal retina, and the expression of Gαo and Gαq by the cells of the cornea; we did not, however, detect expression of Gαi or Gαs. In the PVG, we noted widespread expression of Gαi, Gαo, and Gαq. The expression of Gαs was limited to fine neurites in the lateral and ventral central lobes, as well as large, unipolar neurons in the dorsal central lobes. Our findings suggest that light detection by the eyes of *A. irradians* is conferred primarily by photoreceptors that express Gαo or Gαq, that the corneal cells of scallops may contain sensory receptors and/or receive neural input, and that G protein labeling is useful for visualizing sub-structures and identifying specific populations of cells within the nervous systems of invertebrates.

S1-1 SPERLING, Erik A.*; KOCOT, Kevin M.; Stanford University, University of Alabama; *esper@stanford.edu*
Introduction
Introduction to symposium.

S1-3 SPERLING, EA*; SGP COLLABORATIVE TEAM, _;
Stanford Univeristy; *esper@stanford.edu*
The Temporal and Environmental Context of Early Animal Evolution
Animals originated and evolved during one of the most unique times in Earth history—the Neoproterozoic Era. This talk aims to discuss 1) when landmark events in early animal evolution occurred, and 2) the environmental milieu during these evolutionary milestones, and how such factors may have affected ecosystems and bodyplans. With respect to timing, molecular clock studies—utilizing a diversity of methodologies—agree that animal multicellularity had arisen by ~800 million years ago (Ma) (Tonian), the bilaterian body plan by ~650 Ma (Cryogenian), and divergences between sister phyla by ~560-540 Ma (late Ediacaran). Most purported Tonian and Cryogenian animal body fossils are unlikely to be correctly identified, but independent support for the presence of pre-Ediacaran animals is recorded by organic geochemical biomarkers produced by demosponges. Considering environmental conditions, a large dataset of >10,000 Neoproterozoic-Paleozoic shale samples compiled by the Sedimentary Geochemistry and Paleoenvironments Project is interrogated here to better understand the oceanic landscape early animals inhabited. The results demonstrate that animals evolved in a relatively low-oxygen ocean, although perhaps not considerably less oxygenated than many times in the Paleozoic. Anoxic water columns were generally ferruginous (iron-rich) rather than euxinic (sulfide-rich, as in the modern ocean), and sulfide stress was likely limited. Analyses of sedimentary total organic carbon suggest that the Neoproterozoic ocean had lower primary productivity compared to the preceding Mesoproterozoic or following Paleozoic. Combined with an inability to inhabit productive regions in this low-O2 ocean, earliest animal communities would have likely been more food limited than generally appreciated, leading to important impacts on ecosystem structure and organismal behavior.

P1-40 SPILLANE, JL*; MACMANES, MD; PLACHETZKI, DC; PANKEY, MS; University of New Hampshire;
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Sequencing and Assembly of Field Collected Sponge Genomes
Whole genome sequences provide a window into the organismal biology, ecological significance, and evolutionary history of taxa. However, many organisms exist in association with diverse microbial communities. While these symbioses can drive important ecological interactions, they often prove a hindrance to genome sequencing and assembly. The phylum Porifera represents one such group in which high microbial abundance can complicate and even prevent the generation of accurate genomic data for novel species. Although sponges form one of the earliest branching clades within Animalia and could reveal much about early metazoan evolution, few high quality genomes exist for these organisms. We are developing methods to deal more efficiently with microbial contamination issues, including generating longer sequencing reads and downstream bioinformatics approaches. Here we test the efficacy of these strategies for the genome of the Demosponge *Aplysina cauliformis*, the row pore rope sponge.

P1-233 SPOGEN, RR; SAVAGE, AE; FORSMAN, AM*; University of Central Florida; *anna.forsman@ucf.edu*

Hoppy Microbes: characterizing inter- and intraspecific variation in the amphibian skin microbiome

Here we present results from a comparative study characterizing the adult skin microbiome of five amphibian species sampled at one site in central Florida during spring/summer of 2016. Our objectives were to characterize variation in alpha and beta diversities of skin microbial communities a) among and within host amphibian species, and b) across time for microbiome samples collected from American bullfrogs (*Lithobates catesbianus*), which were sampled at three time points between early May and late June. The other four host species considered were the southern cricket frog (*Acris gryllus*), southern toad (*Anaxyrus terrestris*), American green tree frog (*Hyla cimerea*), and southern leopard frog (*Lithobates sphenacephalus*). We prepared 16S rRNA amplicon libraries from microbial DNA samples, extracted from skin swabs, using universal bacterial primers (515F/806R). Multiplexed libraries were sequenced in one Illumina MiSeq run and the resulting sequence reads were analyzed using QIIME to characterize microbial community composition and to calculate measures of microbiome richness and diversity. We discuss the results of our inter- and intraspecific comparisons in the context of host ecology and disease susceptibility.

S5-3 SPONBERG, S; Georgia Tech; *sponberg@physics.gatech.edu*

Robustness, sensitivity, and necessity in "template" sensing strategies of the hawkmoth

Context dependence, redundancy, multifunctionality, and evolutionary history can obscure a function description of sensory feedback. Given the complexity of neural and mechanical systems, how do we identify common strategies for sensory feedback? One fruitful approach has been careful, systematic characterization of each successive component in a neuromechanical cascade. However there are pitfalls in such interpretation due to the context dependence. As an alternative, we can explicitly analyze and design experimental manipulations that alter the feedback dynamics of a behavior. This approach affords strong, quantitative predictions especially for understanding how the role of sensory feedback changes from one context to another. Here I will focus on dynamic flower handling in hawk moths, a behavior where they must hover in mid air, cast back and forth up to 14 times a second to track flower movement, and do so in exceptionally dim light. Using this system identification approach we have been able determine how redundancy and sufficiency play a role in the integration of mechanosense and vision. We have learned how multiple species tune sensory processing to their preferred ecological contexts and how moths adjust sensing to be robust to changing conditions (unsteady environments, or large mass changes). We can frequently capture these shifts in just one or a few parameters showing that neuromechanical systems can manifest "simple" dynamics, even if the implementation is potentially complex and the underlying neural and mechanical interactions are non-linear. This feedback system identification approach generates descriptions of sensory feedback strategies analogous to the template mechanics models ubiquitous in locomotion -low dimensional targets that are realized, frequently in multiple different ways, in the full complexity of neural systems.

32-3 SPOOL, JA*; JAY, MD; RITERS, LV; University of Wisconsin, Madison; *spool@wisc.edu*

Nest cavity exploration stimulates breeding physiology and alters mRNA expression in the medial preoptic area of female European starlings (Sturnus vulgaris)

To optimize breeding success, animals must coordinate availability of environmental resources with breeding behavior. Yet mechanisms by which resources alter neural systems to fine-tune breeding behavior remain relatively unknown. In female European starlings (*Sturnus vulgaris*), nest cavities are limited resources that are necessary for breeding. Females that explore nest cavities compared to those that do not readily perform sexually-motivated behaviors. This suggests that nest cavity exploration may alter neural systems to stimulate breeding behavior. The present study explored this possibility and examined contributions of additional supplementary cues indicative of the breeding season. We assigned female starlings to either aviaries with 1) standard lab amenities, 2) nest boxes, or 3) nest boxes, plants, flowing water, insects and berries. Aviary condition did not have a significant effect on behavior, physiology, or neural measures. Rather, compared to other females, females housed with nest boxes that explored those boxes had higher estradiol, larger ovarian follicles, higher relative preproenkephalin (PENK) and cannabinoid receptor 1 mRNA, and lower relative levels of D1 and D2 dopamine receptor mRNA in the medial preoptic area (mPOA), a region in which opioids, dopamine, and endocannabinoids act to modify female breeding behaviors. PENK and tyrosine hydroxylase mRNA in the mPOA also positively predicted variance in nest box exploration. These data suggest that for female starlings, nest cavity exploration causally alters breeding physiology and mRNA expression in the mPOA. Thus nest cavity exploration may be a form of self-stimulation required to alter neural systems to fine-tune breeding behavior.

91-7 SPRAYBERRY, K. M.*; TYLAN, C.; SHERIFF, M.; OWEN, D.; MACLEOD, K.; LANGKILDE, T.; Penn State University; *kms6611@psu.edu*

History of stress affects cell-mediated immunity in a lizard

Following exposure to stressors, energy resources are reallocated towards immediate responses, which can divert energy from functions such as the immune system. Which systems are suppressed may be altered by an animal's evolutionary history. The eastern fence lizard (*Sceloporus undulatus*) is a native species impacted by the predatory invasive fire ant (*Solenopsis invicta*). We examined how history of invasion and acute stress treatment affected the cell-mediated immune response of post-gravid lizards. Lizards were captured from sites with long (>70 years) histories of fire ant invasion, and correspondingly higher levels of corticosterone, or those not yet invaded by these ants. All lizards were treated while gravid with either a physiologically relevant dose of the stress-relevant hormone, corticosterone, to simulate the corticosterone response to a fire ant attack, or a vehicle control. We measured the cell-mediated immune response of females post-laying with the phytohemagglutinin skin test. We found that history of exposure to stress (associated with fire ant invasion) and the contemporary stress treatment affect cell-mediated immune response. Lizards treated with corticosterone had reduced immune response compared to controls, and lizards from high-stress fire ant invaded sites had reduced immune response compared to those from low-stress uninvaded sites. These results suggest that the fire ant-induced stress may be immunosuppressing lizards. Future work on how different branches of the immune system respond to environmentally-induced stressors will be informative for predicting and managing these threats.

P2-261 SPRAYBERRY, JDH; SPRAYBERRY, Jordan; Muhlenberg College; *jordannasprayberry@muhlenberg.edu*

The Impact of Polluting Scent on Olfactory Processing in Bumblebees

Bumblebees are critical pollinators in both agricultural and natural ecosystems. Given this, their declining populations are cause for concern. Multiple factors appear to contribute to these declines, including disease, habitat fragmentation, and pesticide exposure. There is some evidence indicating that one of the pathways by which sublethal neonicitinoid pesticide exposure damages population health is via a reduction in foraging efficiency. Given that reproductives are often only produced by the biggest hives, it is logical that reducing foraging efficiency of workers could decrease the reproductive output of the exposed population. Since foraging efficiency is important to colony fitness, it is logical to ask what other anthropogenic activities might cause disruption of foraging behavior. Previous work in our lab has shown that olfactory pollution of a learned floral scent modifies foraging behavior. The most pronounced effects were observed with Manzate, a commercial fungicide. While behavior experiments exposed Bombus impatiens to the headspace of Manzate (a sulfurous scent), the effects of this agrochemical on the olfactory pathway is unclear. To investigate potential modulation of olfactory processing by Manzate odor, we performed multi-unit recordings on antennal lobes in response to lavender odor, Manzate odor, and lavender + Manzate. Preliminary analyses indicate that responses to pollution of lavender odor are not a linear sum of responses to each individual stimulus.

P2-146 SRIDHARAN, VK*; JACKSON, D; HEIN, AM; DANNER, EM; LINDLEY, ST; Univ. of California, Santa Cruz, Eastern Resources Group, Inc., Seattle, National Marine Fisheries Service, National Marine Fisheries Service; *vamsikrishna.sridharan@ucsc.edu*

Abstracting Micro-Scale Fish Movements into a System-Scale Migration Model for an Engineered Urban Estuary

We present a novel agent-based model of juvenile salmon migration through the complex and highly altered Sacramento-San Joaquin Delta in California. The role of water diversions, withdrawals, and flow course alterations on the movement and fate of aquatic organisms in terrestrial flows is still a nascent area of research. In the past, much effort has been expended on three distinct approaches: (i) understanding the locomotive behavior of aquatic organisms at small spatial and temporal scales until just beyond the ballistic range of hydrodynamically assisted movement, (ii) developing hydrodynamic models of water systems involving simple movement models to represent the dispersal of populations, and (iii) developing agent-based ecological models which phenomenologically regress environmental variables on biological responses. Here, we couple the local hydrodynamics within the water column to a random walk model of particles representing simulated salmon to which we ascribe behaviors based on observed migratory patterns in acoustically tagged fish. This is a new approach that bridges the divide between organism-scale movement physics, and population- and system-scale migration dynamics. We show that our mechanistic model captures observed trends in population metrics such as migration time, survival, route selection, and entrainment at water withdrawal facilities. We also discuss how to more accurately bridge organism-scale movement physics with observed migration patterns using more sophisticated correlated movement models.

79-4 SRYGLEY, RB; USDA-Agricultural Research Service; *robert.srygley@ars.usda.gov*

Immune Activation Induced by Microbe-like Challenges Slows Migrating Insects

Whether immune challenges play a role in animal migration is poorly studied, particularly for insects. Mormon crickets *Anabrus simplex* engage in spectacular mass migrations where millions of insects group together and walk in a common direction. Anti-bacterial activity in these insects appears to be compromised by migratory activity. This trade-off is particularly evident when Mormon crickets do not consume sufficient carbohydrates in their diet. If migration compromises anti-bacterial activity, then challenged animals should migrate more slowly as the anti-bacterial immune system is elevated. In order to investigate the effect of immune activation per se, non-living surrogates of bacterial and fungal agents (lipopolysaccharide LPS and laminarin, respectively) were introduced into radiotagged Mormon crickets and the insects' migratory activities and immune responses were measured. Mormon crickets always migrated more slowly when challenged with lipopolysaccharide or laminarin, and in two of the three cases, anti-bacterial activity was inversely proportional to migratory speed. Hence inducible defenses affected migratory activity of the insects. The induction of anti-bacterial activity might directly reduce migratory activity, because a lipid transport protein that is freed from its activity in locomotion can serve to enhance anti-bacterial immunity. Elevation of anti-bacterial activity by both laminarin and LPS suggests that activation of the Toll pathway is not specific to bacteria in Mormon crickets. In conclusion, migration was slowed with microbial-simulated challenges that induced anti-microbial activity.

142-2 STANLEY, EL*; PALUH, DP; BLACKBURN, DC; Florida Museum of Natural History, University of Florida; *elstanley@flmnh.ufl.edu*

Diversification of dermal armor in squamates

The order Squamata contains over 10,000 species, many of which are small-bodied and occupy a low trophic position. As a result, the group displays a bewildering diversity of anti-predation defenses, which include camouflage, audible, visual and chemical warning displays, a broad range of fight/flight behaviors and, universally, armor. All squamates are protected by toughened, keratinized scales but in some lineages these scales are buttressed by osteoderms: bony subdermal plates which strengthen the integument, provide additional ornamentation in the form of spines or keels, and may play a role in calcium sequestration and thermoregulation. Osteoderms are found in several orders of fish, mammals, amphibians, archosaurs, turtles and in 13 extant families of squamates. This study employs comparative phylogenetic analyses of microcomputed Tomography (μCT) data to quantify and investigate the diversity of dermal armor across Squamata, with deep sampling in the families that are known to possess osteoderms. Our analysis reveals multiple independent origins of osteoderms within the order, with three clades—Cordylidae, Anguidae and egerniine skinks—displaying increased rate-shifts in the distribution and extent of their armor. There are repeated losses and gains of ossified armor within these three lineages, and variations in the extent and distribution of osteoderms are shown to be correlated with microhabitat but not climate.

46-2 STAPP, CS*; PAIG-TRAN, EM; California State University, Fullerton; *caitlinstapp@yahoo.com*

Regional Variance in the Structural Properties of Smooth-eye Poacher (Xeneretmus leiops) Scales: A Biomechanical Inspiration for Puncture-Resistant Armor

Agonid poachers are benthic, heavily armored fishes with modified, robust scales that protect against predation. Although the entire body is covered in a fused armor, scales transition from a flattened scale morphology on the ventral surface to a convex scale on the dorsal surface. We hypothesized the dome-shaped dorsal scales of the Smooth-eye poacher, *Xeneretmus leiops*, are mechanically reinforced when compared to the lateral and ventral scales. Smooth-eye poachers (n=28) were separated into intact fish (scales left on) and fish with scales removed (skin exposed). Puncture tests were performed on 1) intact fish, 2) partially descaled fish, and 3) scales that were removed from the fish. We measured the fracture point (strength), Young's modulus (stiffness), and work of fracture (toughness) for each group. Treatments were analyzed using ANOVA with post-hoc Tukey tests. Removed scales were 29% stronger than scales on intact fish and 779% stronger than skin. Removed scales were 27% and 524% stiffer than intact fish and skin, respectively, and 26% tougher than skin. Scales also differed in strength, stiffness, and toughness among the dorsal, lateral, and ventral surfaces of the fish. Dorsal scales were almost twice as strong (9.1MPa ±5.6) as lateral (4.8MPa ±3.9; p=0.005) scales and 1.5 times as strong as ventral scales (5.7MPa±6.9; p=0.019). Dorsal scales were almost twice as stiff (10.4MPa ±8.8) as lateral (5.9MPa ±4.9; p=0.011) and ventral scales (5.3MPa ±3.8; p=0.0009). We predict that the majority of predation attempts are focused along the dorsal surface of this benthic dwelling fish, and therefore, the dome-shaped scales help to increase the resistance to meridional stresses (tooth puncture forces).

P1-297 STAPP, CS*; PAIG-TRAN, EM; California State University, Fullerton; *caitlinstapp@yahoo.com*

Denticulation of the External Genitalia in Chondrichthyans

Sexual reproduction in chondricthyans (sharks and rays) takes place through internal fertilization by the insertion of a male's clasper into a female's cloaca. Although some chondrichthyans mate in the benthic zone, pelagic animals must accomplish this task while swimming. This presents a challenge for animals to maintain a connection between the clasper and cloaca long enough to ensure the successful transfer of sperm to the female. Denticles, dermal tooth-like structures found on the bodies of most cartilaginous fishes, function to reduce drag along the body of a shark by disrupting the boundary layer; however, it is possible that they also help to establish a roughened surface to increase mating success in pelagic breeding species. We hypothesized that the external genitalia of pelagic breeding animals are covered by dermal denticles to function as anchors for maintaining contact during copulation, while animals that breed near the benthos will be devoid of denticles. We used a combination of scanning electron microscopy (SEM) and paraffin histology to determine whether denticles are present on claspers and/or cloacas from 6 pelagic and 6 benthic mating species. We measured the size, density, spacing, and orientation of denticles when present. Denticles occurred on both female and male reproductive structures for all pelagic breeding species, while denticles were absent in demersal breeding species. The presence of denticles on the external genitalia of pelagic breeding species and absence of denticulation on benthic breeding species, suggests this is likely an adaptation that aids in copulation while swimming.

110-2 STEELE, AN*; BELANGER, RM; MOORE, PA; Bowling Green State University, University of Detroit Mercy; *ansteel@bgsu.edu*

Ground Water or Surface Flow: Which Polluted Water Causes More Detrimental Effects in Crustaceans Placed in Stream Mesocosms?

Herbicides are introduced to aquatic systems through variable modes of entry: overland runoff, ground water contamination, and spray drift following application (Davies et al., 2003). Previous work on chemical dispersion has established that exposure pattern of contaminants can differ depending on the method that toxicants are introduced to an aquatic system (Edwards and Moore, 2015; Lahman and Moore, 2015; Wolf et al., 2014). The purpose of this study is to understand how differing routes of exposure to an herbicide, atrazine, alter social behaviors and physiological responses of aquatic organisms. Many studies have indicated that crayfish behaviors and physiology are sensitive to herbicide pollutants, thus these species serve as bioindicators for overall ecosystem health (Weis, 2015; Burba, 1999; Cook and Moore, 2008; Browne and Moore, 2014). This study used agonistic encounters in the crayfish *Orconectes virilis* as a behavioral assay to investigate impact of sublethal concentrations of atrazine (0, 40, 80, and 160 µg/L). Atrazine was delivered by methods mimicking groundwater and surface runoff influx into a flow through exposure arena for a total of 23 hours. Each experimental animal then participated in a dyadic fight trial with unexposed opponents. Fight duration and intensity was calculated and analyzed using a pre-established crayfish ethogram. Experimental crayfish hepatopancreas and abdominal muscle tissue samples were extracted and analyzed for cytochrome P450, glutathione, and acetylcholinesterase levels to discern mechanism of detoxification and mode of action of atrazine. This study demonstrates that method of entry of a toxicant has differential effects on an aquatic organism's health.

92-5 STEENWEG, RJ*; HENNIN, HL; LEGAGNEUX, P; GILCHRIST, HG; CROSSIN, GT; LOVE, OP; Dalhousie Univ., Univ. of Windsor , Univ. de Quebec à Rimouski , Environment and Climate Change Canada, NWRC; *rolandasteenweg@gmail.com*

Mate Guarding in a Diving Seaduck: Energetic Costs And Reproductive Benefits

Reproduction is energetically demanding. For birds investing in energy rich eggs, adequate resource acquisition during the spring pre-breeding period is vital for the formation of eggs and the development of energy stores to last through incubation. In species with female-based mono-parental care, male reproductive investment can occur in the form of mate or territorial defense. The energetic costs associated with mate guarding in the pre-breeding period and the mechanisms linking male condition to female reproductive success are poorly understood. Common eiders nesting at East Bay Island, NU are a model species to explore the relationship between male and female state because both members of each pair are captured and sampled simultaneously during the pre-breeding period. We expected if males expend significant amounts of energy defending their mate from extra-pair copulations or defending her foraging territory then male eider condition would decline and its female mate's condition would increase. Further, we examined whether variation in male energetic physiology (corticosterone, triglycerides, beta-hyroxybutyrate, and immunoglobulin Y) was able to predict the subsequent condition of their paired female, and by extension her subsequent breeding decisions. We hypothesized that males in lower relative condition, with higher CORT and BOH, and lower TRIG and IgY, ultimately benefited via their females laying earlier. These results help explain indirect drivers of reproductive timing and success in common eiders, and identify mechanisms underlying sex-specific reproductive trade-offs.

P3-87 STEENWEG, RJ*; LEGAGNEUX, P; CROSSIN, GT; GILCHRIST, HG; KYSER, TK; LOVE, OP; Dalhousie Univ., Univ. du Quebec à Rimouski, Environment and Climate Change Canada, NWRC, Queen's Univ., Univ. of Windsor;
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Flexibility in the Pairing Phenology of Arctic-Breeding Common Eiders

The ability for individuals to optimally time life-history events can be a key driver for fitness in birds. Pair formation is an important event within the phenology of seasonal breeding because it influences the timing of reproduction. Presumably, the timing of pair-formation reflects the relative costs and benefits of being paired; if paired individuals have better access to limited resources, then it seems logical that selection would favour individuals to pair as soon as possible. If pairing does not influence female condition it might be most adaptive to restrict pairing to later in the spring, closely preceding breeding. Little is presently known about the timing and flexibility of pair formation in arctic-breeding diving ducks. Common eiders nesting in the Arctic at East Bay Island, NU (EBI), are a model species with which to investigate the timing of pairing because both individuals of a pair are simultaneously captured during the pre-breeding period. We apply a recently developed method for determining the overwinter origins of common eiders, based on a stable isotope cluster analysis, to examine the phenology of pair formation. Eiders pairing in winter have a strong correlation in claw isotopic values, and individuals with a weak correlation in claw isotopic values but highly correlated values in blood have likely paired in spring. Our findings suggest that common eiders breeding at EBI exhibit a flexible pairing strategy, with some eiders pairing in the winter, and others in the spring. Pairing strategies impacted the breeding decisions of female eiders and varied between years over distinct winter conditions.

79-5 STEFFENSON, M.M.*; GEMINDEN, R.; VISSER, G.; St. Edward's University, Adams State University;
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Stimulated immune response to Escherichia coli lipopolysaccharides in two subspecies of honeybee (Apis mellifera)

Colony collapse disorder (CCD) has been reported consistently over the past decade, however the root cause of CCD has not been determined. Because of a variety of hypothesized pathogens associated with the progression of CCD, it is becoming increasingly important to understand how the honeybee immune system responds to immunological threats. Our goal in this study was to identify how two different subspecies of honey bees (Italians [*Apis mellifera ligustica*] and ferals [*A. m. scutellata*]) commonly utilized by the pollination and honey industry differ in their immune response. Using *Escherichia coli* lipopolysaccharides (LPS), we simulated a pathogenic infection in each subspecies of bee and then used colorimetric assays to detect and quantify circulating proteins associated with the invertebrate immune response. After feeding bees an LPS solution, they were incubated for 0, 2, or 4 hours to identify how immune investment changes over time since infection. After the allotted time, hemolymph was collected for immunological assessment. Our data show that feral bees survived pathogenic challenge at moderately higher rates than their Italian counterparts. Italian bees also decreased their circulating proteins concentrations over time, while ferals increased these values. Superoxide dismutase (SOD) activity was not statistically significant between subspecies, however both subspecies increased their SOD activity over time. Italians had higher prophenoloxidase (PPO) activity than feral bees at all time-points tested, however feral bees decreased their circulating PPO over time, while Italian bees did not. These data provide evidence that there are differences in how each subspecies combat infections, however the proteins responsible for these differences have not yet be identified.

53-8 STEIN, LR; Colorado State University; *lrstein@colostate.edu*

Integrating personal information and maternal effects across populations in Trinidadian guppies

Individuals often receive information from their environment from multiple sources (population history, parents, and direct experience); therefore animals in natural populations must weigh different sources of information that might not always be in agreement. Here I report a study examining how population history, maternal environment and juvenile experience interact to produce behavioral phenotypes in the Trinidadian guppy (Poecilia reticulata). Mothers from two populations were raised in the lab either with or without predator cues. Offspring were then evenly split and raised either with or without predator cues. I found that in both populations, both maternal effects and juvenile experience produced similar anti-predator phenotypes, suggesting that this plasticity may be adaptive. However, the direction of anti-predator behaviors differed between populations, suggesting interactions between population history and environmental cues. These changes were linked with cortisol adjustments in mothers based on predator experience. Altogether, my results suggest that population history and past selective pressures can influence the relative strength of different sources of information and subsequent behavioral plasticity.

48-5 STEINWORTH, BM*; MARTINDALE, MQ; University of Florida Whitney Laboratory for Marine Bioscience;
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Upside down but not inside out: molecular control of embryogenesis in the jellyfish Cassiopea xamachana

As sister group to Bilateria, Cnidaria provides the opportunity to better understand the evolution of the body plan shared by nearly all metazoans. Extensive work on the anthozoan *Nematostella* and hydrozoans *Hydra* and *Hydractinia* has helped us understand the molecular and developmental programs underpinning the cnidarian body plan. Comparatively little is known about molecular and morphological development within the cnidarian class Scyphozoa, which will provide a fuller view of cnidarian development and evolution and, by extension, a fuller view of metazoan evolution overall. *Cassiopea xamachana* serves as a useful scyphozoan representative for studying development: fertilized eggs and embryos can be collected daily from gravid females, and the full life history can be completed in laboratory conditions. Furthermore, *Cassiopea* reproduces both sexually and asexually, allowing comparison between both modes. To investigate molecular developmental controls, we first describe normal morphology during embryonic development and asexual reproduction, determining that asexual propagules generally retain the polyp identity of tissues rather than recapitulating embryonic development. However, it remains unclear the extent to which molecular signals controlling embryonic development are active during the morphologically distinct asexual reproduction process. To answer this question, we use in situ hybridization to compare expression of known developmental patterning genes in both embryos and asexual propagules of *Cassiopea*.

P2-71 STEPHAN, A*; KY-FRIES, K; NGO, A; PUJADE BUSQUETA, L; ABDOLLAHI, E; SANDHU, G; CROCKER, D; KHUDYAKOV, J; University of the Pacific, Sonoma State University; *jkhudyakov@pacific.edu*

Metabolic Gene Expression in Blubber of Fasting Elephant Seals

Marine mammals such as elephant seals (*Mirounga angustirostris*) routinely fast from food for months while undergoing energetically demanding processes such as molting and reproduction on land. To gain insights into energy homeostasis during fasting, we used quantitative PCR to examine target gene expression in energy-rich blubber tissue collected from elephant seals at the beginning and end of their fasting periods. DNA sequences of transcription factors that regulate lipid metabolism and adipogenesis (FOXO1, DDIT4, PPARG, CEBPD, PGC1, SREBP1), metabolic enzymes (LPL), fatty acid transporters (FABP4), adipokines (LEP, ADIPOQ, RBP4, ANGPTL4), and hormone receptors (ADIPOR1, ADIPOR2, GHR) were identified in a previous elephant seal blubber transcriptome and used to design primers for targeted qPCR assays, with YHWAZ as the reference gene. We found that expression of enzymes such as lipoprotein lipase (LPL) increased, while expression of catabolic regulators such as forkead box protein O1 (FOXO1) decreased during fasting ($p < 0.05$), suggesting that elephant seals tightly regulate lipid stores and their metabolism in blubber tissue during prolonged fasts.

60-1 STEPHENS, JQ*; HUND, AK; IBRAHIM, AS; WICKER, VM; TSUNEKAGE, T; LEVIN, II; Agnes Scott College, University of Colorado; *jstephens@agnesscott.edu*

Does incubation behavior influence nestling telomere length? An egg cross-foster experiment in barn swallows

The natal environment can influence an organism's survival and reproductive success. Telomere length is a trait that is demonstrated to co-vary with measures of organismal performance, and telomere dynamics early in life may have particularly long-lasting consequences. Therefore, it is important to understand the environmental sources of variation that affect telomere length. We studied how incubation behavior influenced relative telomere length in nestling barn swallows (*Hirundo rustica erythrogaster*) using an egg-cross foster experiment. Half the eggs in the nest were switched between synchronously laid eggs from a different nest just prior to the beginning of incubation. This design allows us to decouple genetic and environmental effects on telomere length. Female incubation behavior was quantified by placing thermocouple eggs in the nests to record their temperature profiles. We measured relative telomere length of nine-day old nestlings using qPCR and assigned parentage of nestlings using microsatellite markers. We predicted that eggs receiving consistent, high-quality incubation would result in nestlings with relatively longer telomeres compared to eggs with a less consistent, lower-quality incubation.

S3-2 STERN, DB*; CRANDALL, KA; The George Washington Univ., Computational Biology Insitute; *dbstern@gwmail.gwu.edu*

Convergent and Divergent Transcriptome Evolution in the Eyes of Blind Cave Crayfish

Freshwater crayfishes have evolved to live in caves from surface ancestors independently at different point in the group's evolutionary history, resulting in replicated events of vision loss. This allows us to identify genes that are repeatedly associated with vision loss, ask to what degree evolution takes the same genetic route to vision loss and test if those changes are adaptive in nature. To this end, we take a comparative transcriptomics approach, specifically exploring how evolutionary changes to the transcriptome result in this convergent loss of vision. Using RNA-seq data generated from the eyes of 8 cave and 6 surface species, we identified several thousand homologous gene families expressed. We then tested if expression patterns across these genes were more similar within habitat type or within clades to ask if there are unique gene expression patterns in different cave adapted lineages. We also took a phylogenetic approach to identify a core set of genes associated with vision loss as well as genes uniquely differentially expressed in different instances of vision loss. Finally, we identified genes that displayed a signature of adaptive gene expression variation in the eyes of these species. We found that overall gene expression patterns are more similar among closely related species than they are among distantly related blind or sighted species and that there is a set of genes that are repeatedly associated with vision loss. These results suggest that while the major of gene expression evolution is highly divergent among blind species, there is a set of genes whose expression may be driving the convergent vision loss evolution in this group.

P2-188 STEVENS, LM*; MAYERL, CJ; BLOB, RW; Clemson University; *lmsteve@g.clemson.edu*

Ontogeny of swimming stability and turning performance in the freshwater pleurodire turtle, Emydura subglobosa

Hydrodynamic stability and the ability to turn are two important components of swimming performance in aquatic animals. Stability reduces the energetic costs of swimming, which can constitute most of the daily energy budget of an aquatic animal. In addition, turning performance is critical for both prey capture and predator avoidance. These components of locomotor performance are most commonly measured in adult individuals; however, juveniles often experience stronger selection and higher mortality than adults, placing high demands on these aspects of their locomotor performance. To test how stability and turning performance change in a rigid-bodied, swimming species through ontogeny, we recorded high-speed video of pink-bellied sideneck turtles (*Emydura subglobosa*) as they swam through water following a prey stimulus. We compared the performance of juvenile turtles to adults, and used linear and geometric morphometrics to evaluate changes in limb and body shape as the species increased in size. Our results show that *E. subglobosa* are less stable as juveniles than as adults, especially with respect to heave and sideslip. Juveniles are also more circular in shape than adults, which may contribute to differences in turning performance as size increases. Thus, juvenile turtles do not perform equivalently to adults in these aspects of aquatic locomotion, despite their high vulnerability to pressures that place demands on such performance. Size-related differences in morphology and kinematics likely contribute to these performance differences.

P3-261 STEVENS, AK*; HARRIS, KP; University of Central Florida; *stevensaiesha@knights.ucf.edu*
Oyster Reef Restoration and Living Shoreline Stabilization: Impacts on Infaunal Communities in Shallow-water Estuaries
Infaunal organisms are critical to aquatic food webs and are consumed by many species, including threatened/endangered wading birds and commercially important fishes and crabs. We predicted that infauna would be good indicator taxa to document the transition from dead to living (restored) intertidal oyster reefs and highly eroded to stable shorelines after deploying oyster shell, marshgrass and mangroves. All research was conducted in Mosquito Lagoon, northern Indian River Lagoon system along the east coast of central Florida. Six replicate samples were collected from 12 intertidal oyster reef locations (4 dead control reefs, 4 live control, and 4 restored), and 7 eroding shoreline locations (3 control sites, 4 restored sites). Samples were collected 1-week pre-restoration and 1 week, 1 month, 3 months and then quarterly post-restoration. Once collected in cores and sieved to retain organisms ranging from 2.0 to 0.5 mm, stained and preserved infaunal organisms were sorted out from the sediment in the samples and identified down to the lowest possible taxonomic level. Species density, biomass, and the species diversity data were collected. Results on oyster reefs to date suggest that live reefs have highest species density followed by restored reefs with dead reefs having densities close to zero. Likewise, live oyster reefs contained the largest infaunal organisms, especially among the polychaetes. Living shoreline locations showed a similar trend; stabilized shorelines had higher species density and larger infaunal organisms than the unstabilized sites. In summary, our data document that oyster restoration and shoreline stabilization projects positively impact numerous infaunal species and their associated food webs.

P3-236 STEVENS II, D/R*; BAKER, J/A; FOSTER, S/A; Clark University; *dalstevens@clarku.edu*
The effects of invasive pike on stickleback anti-predator morphology
Invasive species are presenting themselves as a threat to biodiversity as the planet experiences rising temperatures and other forms of rapid environmental change. Thus, it is important to understand how native populations evolve in response to these novel selection pressures if we are to make conservation efforts more effective. Northern pike are an invasive species spreading from the central part of Alaska into the southcentral lowlands. This spread is introducing novel predation pressures to native freshwater threespine stickleback populations, which inhabit many of the freshwater lakes that cover southcentral Alaska. Studying the effects invasive pike have on stickleback populations provides us with a valuable opportunity to examine the effects invasive species have on the evolutionary trajectory of native species, in replicate. Past data suggests that morphological changes that correlated to pike invasion include increases in both pelvic and dorsal spine length and increases in the number of lateral plates. Additionally, a stickleback population dealing with invasive pike displayed decreases in body depth, which may correlate to a change in habitat. However, more data are needed to establish if these changes are indicative of a shared response in all stickleback populations dealing with invasive pike. Here we look to determine whether these few results are general to stickleback, or whether lake-specific trends emerge, by examining morphological changes in additional populations.

17-2 STEVES, I*; BERLINER, P; PINSHOW, B; Ben-Gurion Univ. of the Negev; *steves@post.bgu.ac.il*
Trapdoor of a Desert Wolf Spider (Lycosa sp.) has Little Effect on the Microclimate Inside its Burrow
Animals contribute to the management of their physiological fluxes with the environment by building and living in structures such as burrows. Many species of spiders dig burrows, which they close with silk-hinged trapdoors, soil plugs, or a temporary silk webs. Burrow covers are assumed to serve different functions, such as camouflage; barriers against predators, loose soil or flooding; and maintenance of a favorable hydric and thermal environment for the burrow occupant. We investigated the last in wolf spiders (*Lycosa* sp.) that inhabit loess plains of the Negev Desert, Israel. These, as yet unnamed, lycosids build simple, vertical burrows that reach up to 16 cm in depth and range 0.3-1.7 cm in diameter. When we removed trapdoors from their burrows, the spiders spun webs in their burrow entrances, or alternatively, hid in their burrows until evening. Using fine-gauge thermocouples, we measured a temperature profile that allowed determination of ventilation patterns within the burrows. We found that removing trapdoors increases temperature at the bottom of burrows by ~1 °C at midday in summer. Yet, air from the surface boundary layer did not reach the bottom of the burrows. Direct solar radiation can theoretically reach the bottom of a burrow at midday in summer, based on calculations using natural *Lycosa* sp. burrow dimensions ($n = 181$). Partial heating of the burrow walls may drive thermal convection and diffusion in the burrow. However, temperature differences between open and closed burrow are minor, relative to the daily fluctuations in burrow temperatures. Based on experiments with artificial burrows, we conclude that the small size of the burrow entrance, rather than the trapdoor, may play a greater role in maintaining a favorable environment inside the burrow.

58-4 STEWART, J R *; THOMPSON, M B; East Tennessee State University, University of Sydney, Australia; *stewarjr@etsu.edu*
The Yolk Organ of Scincid Lizards
Development of oviparous amniotes is dependent on functional attributes of tissues that metabolize and transport nutrients from a large mass of yolk. Studies of birds reveal that yolk is overgrown by extraembryonic tissue forming a "yolk sac" which surrounds the yolk. Large endodermal cells on the inner aspect of the yolk sac take up yolk nutrients continuously throughout embryonic development and transport molecules to yolk sac blood vessels. A yolk sac similar to that of birds also develops in lizards and snakes, but in contrast to birds, endodermal cells proliferate within the yolk sac cavity and align along a developing vascular system to form an organ system. We analyzed a developmental series of several species of scincid lizards using light microscopy to characterize the "yolk organ." In these species, all of the yolk is incorporated into large endodermal cells, which align along a vascular network within the yolk sac cavity prior to the height of the embryonic growth phase. Yolk metabolism is intracellular and the endodermal cells transfer nutrients to both arterial and venous circuitry. In addition to the large endodermal cells, the interstitial spaces of the yolk sac cavity contain aggregations of granulocyte-like cells which increase in density in later stages of incubation. Our findings are consistent with recent studies of snakes which reveal unappreciated diversity in structure and function of the egg of amniotes and support an hypothesis that specializations for yolk metabolism diverged in lineages leading to modern squamates and birds.

58-6 STEWART, TA*; UPHAM, NS; Yale University;
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Why so Many Mammae, Mommy? Testing the One-Half Rule in Mammals

Mammals are unique in their capacity to care for young by milk production. In therian mammals (marsupials and placentals), lactation occurs at the mammae, which includes the mammary glands and nipples, or teats. Mammary number varies widely across the clade, up to 26 in tenrecs. Given the obvious link between these structures and parental care, it was proposed that mammary and offspring number coevolve, perhaps with milk production serving as a constraint on litter size. Litter size ranges from 1-32 offspring per litter, but no formal comparisons to mammary number have been conducted across mammalian orders. Previous analyses within Rodentia showed that mean offspring number per litter is approximately one half the mammary number. Here we revisit this 'one-half rule,' which has been broadly extrapolated as general for mammals, and for the first time consider this basic question of reproductive biology in a phylogenetic context. We surveyed primary literature regarding mammalian reproduction, including the online data repositories PanTHERIA and VertNet, to generate a data set that includes information on 2840 species belonging to 1022 genera and all 27 orders. These data were mapped onto a new time calibrated and species-level phylogeny of Mammalia based on a 31-gene supermatrix and built to incorporate uncertainty in branching relationships. Phylogenetic generalized least squares analyses confirm that mammae number and mean litter size coevolve, but suggest that their relationship is closer to one-to-one across all mammals, and that rodents might be unique in their one-half relationship.

136-3 STIENECKER, SL*; MOORE, PA; Bowling Green State University; *sarals@bgsu.edu*
How Social and Environmental Context Shapes Fighting Behavior in Tilapia

Animals engage in aggressive contests frequently as a result of competition over resources. In order to more accurately weigh costs and benefits of withdrawing from an agonistic encounter, participants need to gather relevant information about RHP. Theoretically, what information is used in this critical decision is dependent upon the social and environment context under which animals develop their social skills. The role that these two contexts (social and environmental) play in determining the winner of agonistic interactions was examined. Twenty-four hours to engagement in a staged, dyadic interaction, five male tilapia (*Oreochromis niloticus* X *aureus*) were placed into a treatment in which social composition and resource availability were altered (called priming). After this priming period, animals were paired to fight against size-matched opponents from either the same or different priming treatment. The results from these fights show that combatants from different priming treatments fought differently than those that experienced a similar context prior to engagement in an interaction. These results show that information acquisition and use varies due to social and environment conditions and that the type of assessment used to determine when to withdraw is variable within a species.

128-3 STIER, A*; TSCHIRREN, B; METCALFE, N; MONAGHAN, P; University of Glasgow, University of Exeter;
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Prenatal environment as a modulator of mitochondrial function: new insights from an avian model

Mitochondria are the powerhouse of animal cells. They produce through oxidative phosphorylation more than 90% of the cellular energy (ATP) required for organism's growth, reproduction and maintenance. Yet, our understanding of the factors modulating mitochondrial function is still limited, and for instance we have few information on the importance of the prenatal environment in determining mitochondrial function. The pre-natal environment conveys various information that might be used by the developing organism to adjust its phenotype to the current environmental conditions. Consequently, we might expect that pre-natal environmental conditions will modulate mitochondrial function. To test this hypothesis, we used Japanese quail as a model, and tested the influence of two types of variations in the pre-natal environmental conditions. First, we manipulated the absolute incubation temperature (control vs. low and high) and the stability of incubation temperature (stable vs. unstable) to mimic variations of pre-natal development controlled by parental investment into incubation. Second, we used eggs from selection lines selected either for a high or a low maternal investment measured through egg size to mimic variations of pre-natal development controlled by parental investment into egg production. We evaluated mitochondrial function using standard high-resolution respirometry protocols in both brain and heart samples of embryos. In addition, using individuals from the incubation temperature experiment, we conducted the first longitudinal monitoring of mitochondrial function using red blood cells of the same individuals sampled both at the chick stage and at adulthood. In this talk, I will present the first results of these two experiments and try to shed some light on the importance of pre-natal environmental conditions in influencing mitochondrial function.

P3-39 STIER, A*; ROMESTAING, C; SCHULL, Q; LEFOL, E; ROBIN, JP; ROUSSEL, D; BIZE, P; University of Glasgow, University of Lyon, University of Strasbourg, University of Sherbrooke, University of Strasbourg, University of Aberdeen;
antoine.stier@gmail.com
Measuring mitochondrial function in birds using red blood cells: a case study in the king penguin and perspectives in ecology and evolution

Mitochondria are the powerhouse of animal cells. They produce through oxidative phosphorylation more than 90% of the cellular energy (ATP) required for organism's growth, reproduction and maintenance. Hence, information on mitochondrial function is expected to bring important insights in animal ecology and evolution. Unfortunately, the invasiveness of the procedures required to measure mitochondrial function (e.g. sampling of liver or muscles) has limited its study in wild vertebrate populations so far. Here, we capitalize on the fact that bird red blood cells (RBCs) possess functional mitochondria to describe a minimally-invasive approach to study mitochondrial function using blood samples. In the king penguin, we present a protocol using a high-resolution respirometry system and specific agonists and antagonists enabling the assessment of mitochondrial function in RBCs. The different measures of RBC mitochondrial function were significantly repeatable, were not affected by the handling time of the bird prior to blood sampling (i.e. stress response), and only minimally affected by the storage time of the sample at 4°C up to 24h. Most notably, we showed that mitochondrial parameters measured in RBCs moderately correlated to those measured in the pectoral muscle and were influenced by biological factors such as the fasting status or the sex of the bird. The present study sheds light on the use of RBCs in birds as a valuable and minimally-invasive source of information on mitochondrial function.

6-7 STINSON, CM*; DEBAN, SM; California State Univ., Bakersfield, Univ. of South Florida; *cstinson4@csub.edu*

Functional Morphology of Terrestrial Prey Capture in Salamandrid Salamanders

Salamanders use the hyobranchial apparatus and its associated musculature for tongue projection on land and for suction feeding in water. Hyobranchial apparatus composition and morphology vary across species and different morphologies are better suited for feeding in aquatic versus terrestrial environments. We hypothesized that differences in hyobranchial morphology result in functional trade-offs in feeding performance. We predicted that semi-aquatic and aquatic salamandrids with hyobranchial morphology suited for aquatic feeding will have lower performance, in terms of tongue-projection distance, velocity, acceleration and power, compared to terrestrial salamandrids when feeding in a terrestrial environment. We found that semi-aquatic and aquatic newts had lower tongue-projection performance when compared to the terrestrial salamanders *Chioglossa lusitanica* and *Salamandra salamandra*. The fully aquatic newt, *Paramesotriton labiatus*, has a robust, heavily mineralized hyobranchial apparatus and was unable to project its tongue during terrestrial feeding. Conversely, terrestrial species have slender, cartilaginous hyobranchial apparatus and enlarged tongue pads that coincided with greater tongue projection distance, velocity, acceleration, and power. *Chioglossa* exhibited extreme tongue-projection performance, similar to that seen in elastically projecting plethodontid salamanders; muscle-mass-specific power of tongue projection exceeded 2200 W/kg, more than 350 times that of the next highest performer, *Salamandra*, which reached 6.3 W/kg. These findings reveal that two fully terrestrial salamandrids have morphological specializations that yield greater tongue-projection performance compared to species that naturally feed in both aquatic and terrestrial environments.

P2-148 STOCKEY, RG*; SPERLING, EA; Stanford University; *rstockey@stanford.edu*

How Well Do Environmental Parameters Preserved In The Geologic Record Describe Benthic Ecological Niches?

Ecological niche modelling (ENM) is an emerging technique in modern macroecology for the quantitative prediction of species distributions based on abiotic environmental parameters. The potential to model the relationship between biological populations and multiple stressors in oceanographic systems makes this an attractive approach for predicting ecological responses to global change (at any timescale). The PaleoENM framework has laid the groundwork for the application of ecological niche modelling to the fossil record, opening an exciting research frontier for understanding the interactions between biodiversity and environmental changes in deep time. The paleontological record, unfortunately, does not directly record many of the abiotic environmental variables utilized by benthic marine ecology models in the modern ocean. In this study, we address the potential of the indirect environmental signals available in the geologic record to parametrize the ecological niche space of modern benthic macroinvertebrates by applying machine learning methods to large oceanographic and biodiversity datasets from the benthic ecosystems of Southern California. Random forest algorithms are employed to evaluate the potential of the geologic record to predict modern ecological distributions in the absence of direct oceanographic variables, focusing on bathymetry, sedimentology and geochemistry. Random forest and maximum entropy models are further applied to discrete ecological guilds to investigate the importance of different environmental variables to specific modes of animal life. Through this approach, we hope to advance understanding of how geologically available parameters relate to modern ecological processes and assess the proportion of ecologically relevant environmental information preserved in the geologic record.

122-8 STODDARD, MC*; YONG, EH; AKKAYNAK, D; SHEARD, C; TOBIAS, J; MAHADEVAN, L; Princeton University, Nanyang Technical University, Interuniversity Insitute of Marine Sciences, University of Bristol, Department of Life Sciences, Imperial College London, Harvard University; *mstoddard@princeton.edu*

Evolution of Avian Egg Shape: Morphospace, Mechanics and Flight

Why do eggs come in so many different shapes, from the near-spherical eggs of owls to the pointy eggs of guillemots? We currently lack a global synthesis of how and why egg shape differences evolve. We applied morphological, mechanistic and macroevolutionary analyses to the egg shapes of 1400 bird species. We quantified egg-shape diversity in terms of two variables, asymmetry and ellipticity, allowing us to map the observed morphologies in a two-dimensional morphospace. We then developed a simple mechanical model that can explain the observed diversity of egg shapes. In our model, we suggest that it is the egg's stretchy membrane and not the hard shell that is responsible for differences in egg shape. Using phylogenetic models, we demonstrated that egg shape is correlated with flight ability on a broad taxonomic scale. Adaptations for flight may have had a powerful effect on egg-shape variation in birds.

S8-6 STOLFI, Alberto; Georgia Institute of Technology; *alberto.stolfi@biosci.gatech.edu*

Specification of sensory neurons in the tunicate larva

Recent studies in our closest invertebrate relatives, the tunicates, have refined our models of vertebrate evolution. Here we present our latest findings and most up-to-date summary of other work on the specification of the sensory pathways of the tunicate larval tail, with implications for our understanding of the evolutionary history of vertebrate hair cells and neural crest.

P1-53 STORKS, L*; LEAL, M; University of Missouri - Columbia; *storksle@gmail.com*

The Number of Neurons within the Brain of the Lizard Anolis cristatelllus

Many studies of brain size only look at volume or mass of the brain or region of the brain. However, recent studies have found that the underlying number, size, and density of neurons for a given brain volume or mass varies across individuals, species, and clades. These neuronal variables are related to the brain's computational power, which may be important for understanding cognition. For this project, we have used the isotropic fractionator method to analyze the brain of the lizard *Anolis cristatellus*. We provide data on the number and density of neurons across the telencephalon, cerebellum, and other regions of the brain, as well as how this varies across individuals. We also compare our data on lizards to data published about other vertebrate groups. Future work will combine these data with analyses of cognitive ability.

S7-11 STORKSDIECK, Martin*; RISIEN, Julie; STORKSDIECK, Martin; Oregon State University; *storksdieck@oregonstate.edu*

Developing a Broader Impacts Identity: It's All About You(r Strengths)!

Successful scientists have learned to develop a career trajectory and professional identity around the intellectual merit of their research; the same is not ordinarily true for the broader impacts activities associated with externally funded research. Activities suggested as fulfillments for broader impacts (BI) in a federal grant proposal might focus on undergraduate research or teaching, graduate education, or outreach to K-12 classrooms; the latter may consist of school visits, or might outsource the task to existing university programs who provide relevant services. We offer an alternative concept of addressing BI, something we refer to as Broader Impacts Identity (BII). The concept was developed by co-author Julie Risien, and refers to the deliberate development of a signature program around BI, based on scientists' own personal strengths and preferences, and the nature of the research portfolio that a scientist develops over time. The concept of a BII suggests that the evolution of BI activities associated with a scientist's research portfolio does not have to be ad-hoc, but can follow a deliberate plan. We will present detailed arguments for the need of a BII, provide evidence from a study on the impact of a comprehensive science engagement training program on mostly emerging scientists, and present the outline of a self-assessment tool that helps individuals reflect on their own BII. The tool will be reflective rather than descriptive in nature. It guides scientists through a structured process of aligning personal strengths and interests with the affordances and limitations of their particular research, the research domain within which they conduct their research, and the broader societal significance of the research domain itself.

31-3 STOTT, TP; OLSON, EG; GRAY, JR*; University of Saskatchewan; *jack.gray@usask.ca*

A locust motion-sensitive visual interneuron tracks changes in the velocity of an approaching object

Locusta migratoria is an established neuroethological system for the study of sensory coding within a well-defined motion-sensitive visual neural pathway consisting of two identified interneurons, the Lobula Giant Movement Detector (LGMD) and its postsynaptic partner, the Descending Contralateral Movement Detector (DCMD). The DCMD connects to thoracic interneurons and motor neurons and is implicated in initiating and coordinating avoidance behaviours. This pathway responds robustly to visual motion that occurs in the locust's natural environment. It is most sensitive to motion of objects approaching on a collision course and can also track changes in object trajectory and motion of multiple objects within the visual field. However, it is not known if this pathway responds to objects that change approach velocity, which could be encountered during predator attacks. We recorded from the DCMD while presenting locusts with looming stimuli that increased or decreased in speed during approach. The change in velocity occurred within a behaviourally-relevant time window. We presented stimuli against simple (white) or flow field backgrounds. Results show that the DCMD responds to a velocity decrease with decreased firing rate approximately 150 ms after transition and the post transition peak is reduced compared to the pre-transition peak. Following transition to a higher velocity, the DCMD response is masked by ongoing firing rate modulation. The presence of a low field consistently reduces DCMD response across stimuli. These results suggest that this motion-sensitive pathway is capable of actively adapting to objects that alter their velocity during approach.

24-7 STOVER, KK*; BRAINERD, EL; ROBERTS, TJ; Univ. of California, Irvine, Brown University; *stokris@gmail.com*

Not so fast food: Morphological speed limits in the domestic turkey

The domestic turkey has been artificially selected for increased muscle mass and rapid growth for meat production, reaching over three times the body mass of a wild turkey. We previously reported that domestic turkeys locomote over six times slower than wild turkeys. This study compares the musculoskeletal components of wild and domestic turkeys to identify what morphological features are contributing to the slow locomotion. We collected 121 CT scans during growth from both turkey strains to assess bone dimensional changes. While the domestic turkey's hind limb bones did not get much longer, the femur and tibiotarsus had greater polar moments of area, placing bone where it could better resist torsion and bending. We also investigated potential muscle weakness in the hind limb at the tissue level to see if selection for meat quality rather than function has left them compromised. The physiological cross sectional area of the muscle only scaled with body mass$^{0.79}$, leading to domestic turkeys producing only half as much force per unit body mass (33.9 Nkg^{-1}) as wild turkeys (66.5 Nkg^{-1}). Whole organism morphology changes were investigated by examining differences in muscle proportions between strains. Individual muscles were dissected and weighed. We found that the pectoralis was proportionally larger in the domestic turkey (P=0.0019) contributing to a 26% more anterior center of mass position (P=0.0007). The more anterior CoM in the domestic turkey may lead to other gait changes we observed that were similar to the shuffling gait of Parkinson's patients, associated with increasing stability. We did not see differences at the tissue level between strains; therefore we conclude that the domestic turkey speed limit appears to result from scaling issues and changes in mass distribution.

P1-165 STRATHMANN, RR; Univ. of Washington, Friday Harbor; *rrstrath@uw.edu*

A Field Experiment Demonstrating that the Seafloor can be Very Risky for Planktonic Embryos

In marine environments, most solitary eggs are shed into the plankton, whereas most benthic eggs are grouped into protective capsules, gel masses, or broods. Presumably the seafloor is usually more dangerous than the plankton for a solitary embryo, but field experiments on benthic versus planktonic mortality during early development have been with tethered larvae and larval mimics, not solitary embryos. Here, a field experiment compared survival of embryos offered different degrees of protection from the seafloor. A suspension of embryos at early cleavage stages was introduced into conical chambers whose basal surfaces at the seafloor differed in mesh openings at the sediment surface or in distance from the sediment surface. All embryos were exposed to water that entered through side windows with a 0.08 mm mesh. Surviving embryos hatched as blastulae and swam upward into an apical collection tube, which was later removed for counting. The test site was a coastal lagoon in the NE Pacific. The test embryos were of a sand dollar. Mean proportion of embryos retrieved was 0 and near 0 in chambers floored with 0.9 mm and 0.08 mm meshes at the sediment surface. Mean proportion retrieved was greater (mean = 0.40) in chambers floored with a 0.08 mm mesh several cm above the sediment surface and still greater (mean = 0.68) in chambers floored with a complete barrier at the sediment surface. The mean retrieval in the treatment with the complete basal barrier was close to the retrieval when chambers were in laboratory aquaria without sediment. In this experiment survival therefore ranged from zero without protection from marine sediments to high with protection from the sediment. Most of the earth is covered by marine sediments. This method for field experiments can be employed at varied sites and with varied embryos to test the generality of these results.

34-9 STREBEL, B*; HAN, Y; LI, C; Johns Hopkins University; *blakestrebel2018@u.northwestern.edu*

A novel terrain treadmill to study animal locomotion in complex 3-D terrains

A major challenge to understanding terrestrial locomotion in complex natural terrain is the lack of tools to perform controlled, systematic experiments in the laboratory. Recent progress was made by creating complex 3-D terrain arenas of obstacles such as grass-like beams with controlled and variable geometry and stiffness. However, these terrain arenas only allow experiments at relatively small temporal and spatial scales (~10 stride cycles, ~10 body length) with low resolution observations (~5% pixels representing the animal). Here, we create the first terrain treadmill to enable high resolution observations of locomotion in complex 3-D terrains over a long time and a large distance, analogous to treadmills for studying continuous running and walking on flat, rigid ground. Our terrain treadmill consists of two rigidly attached concentric spheres. The animal moves through modular terrain on the inner sphere, while the transparent outer sphere allows its position to be tracked in real time. This is then used to rotate the spheres opposite to the animal via closed-loop control to keep it on top. To demonstrate the usefulness of our device, we tested its performance in eliciting sustained locomotion of the discoid cockroach through cluttered pillar obstacles. In a single, continuous trial, the animal moved through pillars for 25 minutes (2500 stride cycles) over 100 m (2000 body length). For 99.7% of the experiment, the terrain treadmill contained the animal within a 5 cm2 region even at locomotion speeds of up to 10 body length/s, enabling high resolution observations (25% pixels representing the animal). Our terrain treadmill not only increased limits of experiment duration (by 250×), distance (by 200×), and resolution (by 5×), but is also opening doors to studying sensorimotor control in complex terrains.

P2-208 STRICKLEN, B.*; BALLESTER, A.; BOND, L.; GOULD, F.; GERMAN, R.; Northeast Ohio Medical University , Northeast Ohio Medical University; *bstricklen@neomed.edu*

Integration of Respiration and Swallowing Performance after Sensory Nerve Lesion in Infant Pigs

To prevent liquid entering the airway while feeding, infants must be able to coordinate breathing and swallowing. The removal of sensory signals (RLN in particular) changes kinematics, muscle function and performance of swallowing. The specific impact of a recurrent laryngeal nerve lesion on the interaction between timing of respiration and the success of swallowing, and how this interaction changes with development, is unknown. We recorded fourteen infant pigs at two ages, 7 days (early infancy) and 17 days (near weaning age). Eleven control pigs and three pigs with a recurrent laryngeal nerve lesion were recorded while feeding with highspeed videofluoroscopy. We measured the timing of a swallow relative to inspiration at the thoracic region, and the success of the swallow. Younger pigs with lesion had safer swallows than control animals, with less variability in the time of the swallow. By day 17, pigs with lesions swallowed more successfully. The controls had more unsafe swallows on day 17 than day 7. The delay in timing of respiration increased as the control and lesion pigs age. The control and lesion pigs increased the delay in timing of respiration with unsafe swallows on day 7. By day 17, the control pigs increased the delay in time when performing unsafe swallows, while the lesion animals increased the delay in time when performing safe swallows. Lesion pigs become more successful at producing safer swallows at an extended amount of time with age, suggesting that lesion animals are by some mechanism adapting to perform safer swallows. The timing of respiration does not appear to cause aspiration in the controls.

S7-8 STROHECKER, Carol; HRISTOV, Nickolay/I*; College of Design, University of Minnesota, UNC Center for Design Innovation, Winston-Salem State University; *hristovn@cdiunc.org*

Designing for Broad Understanding of Science

With the acceleration and increasing complexity of macro-scale problems such as climate change, the need for scientists to ensure that their work is understood has become urgent. As citizens and as recipients of public funds for research, scientists have an obligation to communicate their findings in ways many people can understand. However, developing translations that are broadly accessible without being "dumbed down" can be challenging. Fortunately, tenets of visual literacy, combined with narrative methods, can help to convey scientific knowledge with fidelity, while sustaining viewers' interest. Here we outline strategies for such translating, with an emphasis on visual approaches. Among the examples is an innovative, NSF-funded professional development initiative in which National Park rangers use scientists' imagery to create compelling explanations for the visiting public. Thoughtful visualizations based on interpretive images, motion picture, 3D animations and augmented, immersive experiences, complement the impact of the natural resource and enhance the role of the park ranger. The visualizations become scaffolds for exchanges in which the ranger transcends the traditional roles of information-holder and presenter, to facilitate provocative conversations that provide members of the public with enjoyable experiences and well-founded bases for reflection. The process of generating the supporting visualizations benefits from partnerships with design professionals, who develop opportunities for engaging the public by translating important scientific findings and messages in compelling and memorable ways.

65-4 STROM, MS*; EBENSPERGER, LA; HAYES, LD; New Mexico State University, Pontificia Universidad Católica de Chile, University of Tennessee, Chattanooga; *mstrom90@gmail.com*

Habitat-specific fitness benefits of sociality in Octodon degus

Recent debate has focused on how ecology shapes the evolution of group-living and cooperation in social vertebrates. Evidence suggests that group-living and cooperation enhance reproductive success under harsh local conditions in some species. Across two years, I studied two populations of *Octodon degus*, a plurally breeding rodent, to answer three questions: (1) Does living in large groups and having strong network strength improve access to resources in harsh environments? (2) Does increased access to resources improve the reproductive success of females? (3) Does living in large groups and having strong network strength improve reproductive success of females in harsh environments? I quantified group sizes and social network strength, ecological conditions at burrow systems, and per capita offspring weaned of social groups to answer these questions. I found site- and year-specific relationships in partial support of my predictions, demonstrating habitat-specific costs and benefits of social group-living and cooperation. I found associations between social network strength and food abundance in the site exhibiting more harsh conditions. In both sites, access to food and burrow openings did not improve reproductive success of females. In one site characterized by more harsh conditions, social network strength, but not group size, was associated with reproductive success of females.

P3-168 STROM, J; REMBERT, K; MULAWA, E; DONAHUE, S; GHALAMBOR, CK*; Colorado State University; *cameron1@colostate.edu*

Trinidadian guppies have evolved repeated reductions in bone density following the colonization of low predation streams, but why?

Empirical studies of adaptation in nature reveal that trade-offs between competing functions are common. Such trade-offs are expected because whole organisms represent integrated systems, such that changes in any one trait will impact other traits. Bone and skeletal attributes represent a highly-integrated trait that influences a wide range of functions, including locomotion, protection, and mineral storage, but whether populations adapted to different environment exhibit different bone structure has gone largely unexplored. We compared the bone structure of field collected Trinidadian guppies adapted to lowland streams where predators are common, and headwater streams where predators are rare. We found significant and parallel differences in the exo- and endo-skeletons. Specifically, guppies from lowland streams had reduced bone density and mineralization of the exterior scales and endoskeleton, while their upstream counterparts had highly mineralized scales and skeletons. These differences appear to have a genetic basis, as the differences persisted after rearing guppies in the lab on the same diet. We discuss alternative hypotheses for why these differences might be adaptive, and the implications for how traits are integrated across these contrasting environments.

138-1 STROTHER, JA*; PAIG-TRAN, EWM; BOLLA, V; Oregon State University, California State University, Fullerton; *james.a.strother@gmail.com*

When is a vortex a filter? Examining the filtering apparatus of mobulid fishes using computational fluid dynamics.

Mobulid fishes are large filter-feeding elasmobranchs that capture zooplankton using a filtering apparatus formed from highly modified gill rakers. Many filter-feeding animals capture prey using sieve filters, in which water is forced through an array of pores and any particles smaller than the pore size are trapped. However, previous studies using physical models have indicated that the filtering apparatus of mobulid fishes operates via a different mechanism. Water flowing over the apparatus appears to produce a train of captive vortices that repel zooplankton away from the filtering apparatus and concentrates them within the buccal cavity. However, the hydrodynamic forces that give rise to this filtering effect are still not well understood. In this study, we constructed a computational fluid dynamics model of the filtering apparatus and calculated the flow velocities around the filter. We then simulated the trajectory of solid particles traveling through the calculated flow field using equations of motion that include inertia, added mass, drag, contact forces, and shear-induced lift. These simulations predict that captive vortices can function as filters, and this model provides new insights into the hydrodynamic forces that produce this effect.

P3-182 STRUBLE, MK*; GARDNER, J; GIBB, A; Northern Arizona University, Montana State Univrsity; *strublemikayla@gmail.com*

The Evolution of Grasping Behavior in Birds and Associated Pedal Adaptations

Because they are obligate bipeds that exploit a variety of ecological niches, modern birds experience a great deal of variation in the intensity of the biomechanical stresses experienced by their feet, which, in turn, influences pedal (foot) morphology. Increased pedal grasping capabilities are consistently associated with relative shortening of proximal phalanges, the elements of the foot which are nearest the articulation with the tarsometatarsus. To quantify the relationships between behavior, inferred biomechanical stress, and pedal morphology, we binned modern birds into raptorial, clinging, perching, and ground/water dwelling classifications based on intensity and frequency of grasping behavior and collected morphological data for species in each bin. Using current Avian phylogenic trees, we employed Bayesian statistics to model, for each behavioral bin, the relationships between the length of the penultimate and proximal phalangeals of digits II to IV. We found significant differences in each of the regression models between these four bins and suggest a timeline for the evolution of grasping behavior in modern Aves. In addition, we applied the morphology-behavior relationships observed in modern birds to extinct groups. We measured fossil specimens of Enantiornithines (Mesozoic toothed birds), basal birds, and non-avian theropods in an effort to infer behavior and diet of these lineages during the Mesozoic. With these analyses, we found evidence for evolution of raptorial and perching behavior in Enantiornithines independent from modern Aves. By inferring feeding mode from pedal morphology, we can add depth and detail to our understanding of the predator-prey relationships of the Mesozoic.

17-1 STUPSKI, SD*; SCHILDER, RJ; Pennsylvania State University; *sqs6157@psu.edu*

Developing Biophysical Heat Budget Models in Three Hymenopteran Species

The foraging activities of bees and hornets are directly tied to their ability to 1) maintain a minimum thoracic temperature required for sustained flight and 2) their ability to diffuse heat so as not to overheat to a lethal temperature. In the face of climate change, the atmospheric conditions which contribute to heat gain and loss are changing rapidly globally, thereby changing the heat transfer dynamics and microclimate usage of endothermic hymenopterans. It is therefore important to understand, at a biophysical level, how meteorological conditions can extend or limit the thermal budget of these important pollinator species. Here, we present a heat transfer model for three hymenopteran species, the honeybee ,*Apis mellifera*, the bumblebee, *Bombus impatiens*, and the bald-faced hornet *Dolichovespula maculata*. The model is experimentally parameterized along the major routes of heat gain and loss: convective heat transfer, absorption of solar radiation, metabolic activity, evaporative water loss, and radiative heat transfer. Then, using physiological data on the minimum internal temperatures needed for flight and the maximum temperature before lethal overheating, we solve for the time it will take workers of each species to reach either the minimum or maximum heat threshold under variable atmospheric conditions.

67-1 STYGA, JM*; HOUSLAY, TM; WILSON, AJ; EARLEY, RL; The University of Alabama, University of Exeter-Penryn ; *jmstyga@crimson.ua.edu*

Ontogeny of the Morphology-performance Axis in the Amphibious, Self-fertilizing Hermaphroditic Fish (Kryptolebias marmoratus)

Quantitatively linking morphology with performance at one developmental stage is important because it allows us to better understand the functional, ecological, and evolutionary implications of morphological diversity. Links between morphology and performance may also be age dependent as the architecture needed for optimal performance may be underdeveloped in young animals. Few studies have examined how the relationship between form and function changes across ontogeny. Here, we assess this link in the amphibious, simultaneously hermaphroditic mangrove rivulus (Kryptolebias marmoratus) fish. This species is capable of transporting itself over terrestrial landscapes to new aquatic habitats using a behavior known as tail-flip jumping. Using tactile stimulation during timed trials and a clearing and staining procedure, we assess jumping performance and variance in caudal bone dimensions. We test the hypotheses that: i) morphology and jumping performance vary as a function of age; ii) jumping performance increases significantly with age, independent of size; and iii) phenotypic variance and covariance among morphological and performance traits change across ontogeny. We focus on describing variance in bones within the caudal peduncle (i.e. parahypural, epural, and hypurals) because this region is intimately involved in terrestrial jumping. In support of our hypotheses, we found a significant increase in size-adjusted jumping performance with age, and modification to the correlation structure among traits across ontogeny. The significant link between form and function found at prematurity, however, disappeared at later stages in ontogeny. This implies that different functional mechanisms may be associated with high jumping performance at different stages in development.

P3-169 SULLIVAN, SP*; HOLLIDAY, CM; BAILLEUL, AM; MIDDLETON, KM; Univ. of Missouri, Columbia; *spsullivan@mail.missouri.edu*

Digital Reconstruction of the Avian Pectoral Girdle with Implications for Furcula Function

The avian wishbone, or furcula, is formed by a fusion of paired clavicles and/or a modified interclavicle, variably connects to the coracoid and sternum, and serves as the cranial-most attachment of the m. pectoralis in most birds. Although several overlapping functional hypotheses have been proposed for furcular morphology, both static (related to posture and support) and dynamic (related to flight style and respiration), the bone remains an enigmatic part of the avian pectoral girdle. In particular, we have little understanding of the element's substantial variation among birds in its overall shape, cross-section, mechanical properties, and associated soft tissues. Despite the hypothesized significance of the furcula in the origin of flight and diversification of flight styles, much further work needs to be done to characterize its functional properties among extant taxa. We used contrast-enhanced CT imaging, joint histology, and digital muscle fiber orientation reconstruction to comprehensively investigate the structure and function of the furcula in the European starling (*Sturnus*), budgerigar (*Melopsittacus*), and domestic chicken (*Gallus*). Both starlings and budgerigars are small, intermittent-flapping fliers (as opposed to continuous-flapping and soaring fliers) that predominantly utilize flap-gliding and flap-bounding, respectively. Chickens, on the other hand, are poor fliers despite their well-developed pectoral musculature. We found marked differences in muscle attachments, muscle fiber orientation, and ligamentous soft tissues consistent with flight style variation in our sample. These results will form the basis of future comparative studies aiming to examine the functional relevance of bird pectoral anatomy to the evolution of the clade.

P2-165 SULLIVAN, CM*; CARR, JA; TYTELL, ED; Emmanuel College, Tufts University; *sullivanc@emmanuel.edu*

Muscle responds differently to lengthening perturbations depending on both activation and perturbation phase

Organisms often are required to locomote in a changing environment while remaining stable. In order to do so, they must be able to quickly respond to a perturbation during locomotion. Muscles and other elastic elements in the body can respond to perturbations even before the nervous system can sense them. Moreover, the muscles change length and receive an activation signal, which means they may respond differently to the same perturbation at different times. My study investigates how muscle responds to short perturbations in length during a standard work loop protocol with different activation and perturbation phases. Isolated muscle samples from silver lamprey (*Ichthyomyzon unicuspis*) were sinusoidally shortened and lengthened at 1Hz and then stimulated at four phases. The muscle segment was then given lengthening perturbations at four different phases. The resulting muscle force and length were recorded. Maximum force, stiffness, and damping were quantified and compared between the activation and perturbation phases using ANOVA. When the muscle was perturbed at its maximum length, the maximum force was significantly higher than those of other perturbation phases. Similarly, muscle stiffness, as indicated by the slope of the force response during perturbation, was found to be greatest if the muscle was perturbed at the maximum length. This response may be reflective of the muscle's intrinsic length-tension properties where muscles acting closer to plateau produce more force. At other perturbation phases, the muscle damping was much higher. The time course of the response to perturbations also differed depending on both perturbation and activation phase. In conclusion, both the phase of activation and perturbation affect how muscles respond to destabilizing length change.

91-6 SULLIVAN, TJ*; NEIGEL, JE; University of Arkansas, University of Louisiana at Lafayette; *tjsulliv@uark.edu*

A case-control study of immune related sequence polymorphism in the blue crab Callinectes sapidus

Infectious diseases are a pervasive threat to marine populations and ecosystems. Identification of genes that contribute to variation in disease resistance is an essential step towards assessing the potential for disease resistance to evolve. Here we use case-control comparisons to screen variants of candidate disease-resistance genes of the blue crab, *Callinectes sapidus* for association with infection by pathogenic *Vibrio* spp. bacteria and the dinoflagellate *Hematodinium perezi*. Transcripts of candidate genes were identified by functional annotation of blue crab transcriptomes. Single nucleotide polymorphisms (SNPs) in ~200 of these candidate resistance genes were identified in alignments of transcripts from multiple individuals. Blue crabs from the coast of Louisiana were genotyped for these SNPs and tested for infection by pathogenic *Vibrio* bacteria and the dinoflagellate *Hematodinium perezi* with PCR-based assays. We then used latent factor mixed models to test for associations between SNPs and pathogens. Two SNPs were associated with infection by *H. perezi*, while 10 SNPs and 1 multi-SNP haplotype were associated with infection by *Vibrio* spp. Annotated biochemical functions for these candidate resistance genes include: ubiquitination, wound healing, signaling, lysosome function, and phagocytosis. Lastly, we identified correlations between resistant allele frequency and stressful environmental conditions in marshes throughout Louisiana and changes in resistant allele frequency among life stages (larvae, juvenile, and adult) that suggest the potential for selection at these candidate gene regions.

S4-8 SUMIDA, Stuart*; JEFCOAT, Brian; California State University San Bernardino, DreamWorks Feature Animation; *ssumida@csusb.edu*

Anatomy, Animation and Visual Effects: the Reciprocal Story-telling Tools of Biology and Film-making

Locomotion studies, biomechanics, and particularly vertebrate paleontology have had a deep influence on the development of motion pictures, animation, and computer generated visual effects. Biologically straightforward concepts such as morphological correlates of diet, sexual dimorphism, and ontogenetic change have become powerful tools for animators and visual effects artists. Despite this deep debt to the ever-increasing role of science and technology in film making, scientists often forget to mine the communication strategies of their science-savvy entertainment industry kin. Further, many of the tools of the film industry are making a direct impact on basic research or have the potential to do so. Many researchers already use software packages such as Autodesk MAYA for three-dimensional imaging and modeling. MAYA can be further used as hypothesis generating and testing tools. This is particularly useful in the study of skeletal biomechanics. Any modeled skeletal motion that results in element interpenetration in three-dimensional space is necessarily excluded from viable hypotheses of motion. This is particularly useful in paleontological hypothesis generation, reducing significantly the amount of arm-waving and unsupported pronouncements, and instead demanding three-dimensionally viable hypotheses for ranges of movement (of which actual biological ranges of motion are then a subset). As scientists we all have a duty to inform and teach the public. Some of the concepts and stories we offer to film makers are compelling stories to offer to our own students, and can be as compelling to the public as the entertainment they often facilitate. STEM is critically important. But adding art to produce STEAM helps to build a potentially unstoppable tool for science communication and the public good.

P1-270 SUMMERS, D.A.*; DONATELLI, C.M.; KENALEY, C.P.; SUMMERS, Dexter; Harvard University, Tufts University, Boston College; *dexter@mightycheese.com*

The Material Properties of Fish Skin and Their Relevance to Ecology and Morphology

The convergent architecture of the skin of aquatic vertebrates, with its multi-layer, cross-helically arranged collagen fibers, has led biomechanist to infer that the dermis plays an important functional role in undulatory swimming. To date, two functions have been proposed for the skin of ray-finned fishes: (1) an exotendon in which the cross-helical fibers resist deformation and transmit force down the exterior of the body and (2) a direct-force transmission device in which the contractile tension developed in anterior muscle segments is propagated to the peduncle and caudal fin. In addition, skin stiffness may be related to ecological and morphological parameters that demand different optima concerning body thrust production (including swimming mode, body shape, and feeding). In this study we set out to determine the skin stiffness of fishes demonstrating a variety of swimming modes and feeding strategies, from burst swimming ambushers to steady swimming foragers. We laser cut prepared skin samples and tested each in a custom, Ardiuno-based biaxial testing rig that imposed positive strain along the longitudinal axis of the sample while hoop stress was kept constant. Across all species at 10% longitudinal strain and a constant hoop stress of 0.1 MPa, longitudinal stiffness ranged from 23 and 52 kPa and from 46 and 270 kPa at 30%. From these data, we found a positive relationship between skin stiffness and species demonstrating high-acceleration swimming performance. We also found that for two out of out four flatfishes, skin stiffness showed eyed versus blind side asymmetry. Together, our results suggest that the skin and its material properties contribute directly to swimming performance capabilities and a number of ecological demands.

S3-10 SUMNER-ROONEY, LH*; SIGWART, JD; SMITH, L; MCAFEE, J; WILLIAMS, ST; Oxford University Museum of Natural History, Univ. of California, Berkeley; Queen's University Belfast, Natural History Museum, London, Queen's University Belfast, Natural History Museum, London; *lauren.sumner-rooney@oum.ox.ac.uk*

Repeated Eye Reduction Events Reveal Multiple Pathways to Loss in Deep-Sea Snails

Eye loss occurs in many troglobitic, fossorial and deep-sea animals but there is no clear consensus on its evolutionary mechanism. Given the highly conserved and pleiotropic nature of many genes instrumental to eye development, degeneration might be expected to follow consistent evolutionary trajectories in closely-related animals. Molluscs are renowned for the enormous diversity of eye designs they exhibit, and they occupy a wide variety of light environments. Eyeless deep-sea gastropods offer a model study system, both taxonomically and biogeographically, for examining broader evolutionary processes involved in loss and regression. We conducted a comparative study of ocular anatomy in solariellid snails from deep and shallow marine habitats using morphological, histological and tomographic techniques, contextualised phylogenetically. Independent instances of reduction follow numerous different morphological trajectories. We estimate eye loss has evolved at least seven times within Solariellidae, in at least three different ways: characters such as pigmentation loss, obstruction of eye aperture and 'lens' degeneration can occur in any order. In one instance, two morphologically distinct reduction pathways appear within a single genus, *Bathymophila*. Even amongst closely related animals living at similar depths and presumably with similar selective pressures, the processes leading to eye loss have more evolutionary plasticity than previously realised. Although there is selective pressure driving eye reduction, it is apparently not morphologically or developmentally constrained as has been suggested by previous studies.

P1-89 SUR, S*; SHARMA, A; KUMAR, V; University of Delhi, Delhi; *drvkumar11@gmail.com*

Temperature Affects Photoperiod-induced Gene Expressions in the Hypothalamus, Liver and Muscle in a Migratory Songbird: Insights into Genetic Regulation of Seasonal Physiology and Behaviour

We investigated the role of temperature in photoperiodic regulation of seasonal processes in migratory redheaded buntings (*Emberiza bruniceps*), which is photosensitive and responds to long photoperiods. Buntings were exposed to long photoperiod (13L:11D) for 7 or 19 days at low (22˚± 2˚C) or high (38˚± 2˚C) temperature, with a group maintained on non-inductive short photoperiod (8L: 16D). Birds showed the initiation of body fattening and testis growth under long, but not short, photoperiod. Further, we measured the expression of genes involved in thermal sensation (*trpv4, trpm8, bdnf, adcyap1*), lipid regulation (*lpl*) and epigenetic modifications (*dnmt3a, dnmt3b, tet2, hat1*) in the hypothalamus, in fatty acid metabolism (*elovl6, scd, dgat2, srebf1, fads2*) in the liver, and in fatty acid transport (*cd36, fabp3*), response to hypoxia (*hif1α*) and muscular strength (*myod*) in the muscle. We found both photoperiod and temperature effects on mRNA expression levels, although with gene- and/ or tissue specific differences. Hypothalamic expression of *dnmt3b* and *tet2* genes was altered by the photoperiod, and of *trpm8* by the temperature. While *elovl6, dgat2, scd, srebf1* expressions were affected by photoperiod and/or temperature in the liver, *cd36* and *fabp3* expressions were affected by temperature in the muscle. These results show molecular changes in response to both photoperiod and temperature, and give insights how possibly temperature might modulate the photoperiod-induced seasonal responses in migratory species.

P3-35 SURIYAMPOLA, P/S*; MARTINS, E/P; Indiana University, Arizona State University; *piyumika101@yahoo.com*

Shifting the Primary Sensory Modality Leads to Persistent Changes in Sensory, But Not Social Behavior in Adult Zebrafish Danio rerio

Animals can shift from one primary sensory modality to another, when changing environments make the primary modality less useful or reliable. However, such plasticity may come at a cost if it requires also changes to physiology or behavior, or if the environment then changes back again. Sensory shifts may also be less possible in adults or outside of critical developmental periods. Here, we ask about the broader phenotypic impacts of sensory shifts. Specifically, we housed adult zebrafish for six weeks in either constantly-clear water or in water that was periodically turbid (i.e., visually unreliable). We then compared the two groups in terms of their (1) preference for visual versus olfactory cues, (2) response to a visual-motor stimulus used to measure visual physiology, and (3) behavior. We found that fish with experience in the visually-unreliable context had a stronger preference for olfactory as opposed to visual cues, confirming a shift in their primary sensory modality. These fish also responded less robustly in physiological tests, suggesting a more general change in visual-motor behavior. However, latency to respond to visual or chemical cues, plasticity in response to the immediate context in which they were tested, and other behavioral measures (e.g., shoal cohesion, aggression, and activity level) did not differ between treatments. Taken together, these results suggest that experiences in particular physical contexts may have profound effects on the use of different sensory modalities and visual-motor behavior. In addition, shifts between sensory modalities may help animals to buffer other forms of behavior from major changes in the environment.

P1-295 SUSTAITA, D*; HERNANDEZ, J; FARABAUGH, SM; SUSTAITA, Diego; California State University, San Marcos, San Diego Zoo Institute for Conservation Research; *dsustaita@csusm.edu*

Comparison of predatory kinematics between adult and juvenile San Clemente Loggerhead Shrikes

Loggerhead shrikes are medium-sized passerines that eat insects and small vertebrates. Previous work on their hunting behavior, morphology, and bite performance has demonstrated the importance of the beak and biting for killing and subduing vertebrate prey. However, little is known regarding the ontogeny of predatory performance, given the difficulties of observing predatory attacks in the wild. We studied the predatory kinematics of adult and juvenile San Clemente Loggerhead Shrikes, in association with a captive breeding and release program on San Clemente Island, CA. We present the results of a two-tiered analysis, focusing on (1) overall prey capture and handling efficiencies, and (2) 3-D prey-striking and biting kinematics. With regard to (1), we found that juveniles typically required longer handling times and delivered more bites to immobilize vertebrate prey, but used fewer prey-shaking movements than did adults, although the rates of these behaviors were similar between age classes. With regard to (2), we found that adults struck mice with greater average velocities than they did crickets, and that prey-striking and jaw-closing average velocities tended to be higher in juveniles than in adults when attacking crickets. Taken together, these results suggest that adults might rely on different strategies for immobilizing vertebrate prey (e.g., more on prey shaking, less on biting), and more appropriately match their attack velocities to the demands of their prey. Juvenile birds are known to under-perform relative to adults in foraging; these data suggest specific mechanisms by which this occurs in shrikes, and potentially other predatory taxa.

134-1 SUTHERLAND, KR*; GEMMELL, BJ; COLIN, SP; COSTELLO, JH; University of Oregon, University of South Florida, Marine Biological Laboratory/ Roger Williams University, Marine Biological Laboratory/ Providence College; *ksuth@uoregon.edu*

Individual zooid kinematics underlying agility and maneuverability in the siphonophore Nanomia bijuga

Siphonophores and salps are colonial marine organisms comprising multiple swimming units that coordinate forward and reverse swimming. Recent work has focused on the role of coordination in achieving hydrodynamic efficiency and, in some cases, impressive vertical migrations by these multi-jet swimmers. Currently, we are investigating how individual kinematics by the nectophores (swimming bells) and jet wakes contribute to fast swimming, agility and maneuverability in the siphonophore *Nanomia bijuga*. High speed video of nectophore kinematics and PIV of the resultant jet wakes show the velar mechanics underlying agility and maneuverability. Rapid changes in the velar aperture area and shape produce high speed jets and high angular velocities during turning (agility). Fine-tuning of the velar angle during jetting achieves a low turning radius (maneuverability). The details of velum kinematics and associated fluid mechanics explain how siphonophores effectively navigate three-dimensional space and could be applied to exit flow parameters in multijet underwater vehicles.

31-7 SUVER, MP*; ALVAREZ-SALVADO, E; MATHESON, AM; SARKAR, S; DAMIATA, M; NAGEL, KI; NYU Neuroscience Institute; *suver.marie@gmail.com*

Wind direction encoding in the fruit fly

Insects use wind cues to guide many behaviors. For example, in search of food or mates, insects will turn upwind upon encountering an attractive odor. This behavior relies on the animal's ability to gauge wind direction. Flies detect wind direction using antennal mechanosensors that project to a brain region called the antennal mechanosensory and motor center (AMMC). We set out to understand how wind direction is encoded downstream of this primary processing center by using whole-cell electrophysiology and a novel stimulus paradigm. We have found that wind direction is encoded by at least two classes of neurons that project from the AMMC to a second-order wind processing center in the brain. These neurons each receive input from the ipsilateral antenna and show distinct direction tuning. Further, we have identified a novel set of putative third-order projection neurons that encode wind direction with greater dynamic range and discriminability than either of the two types of second-order neurons. We find that these neurons combine input from both antennae, and that bilateral input is critical for their large dynamic range and increased discriminability. Next, we analyzed antennal movements in response to directional wind stimuli and found that comparison of signals across the two antennae can resolve ambiguities in the signal from a single antenna, and improve discriminability in the region in front of the fly. We are currently testing a simple model for how third-order responses are generated based on these results using genetic manipulations and physiology. Lastly, we hope to elucidate the role of these neurons in wind-guided navigation through ongoing experiments using a walking behavioral assay and genetic silencing.

P2-100 SUYDAM, RC*; SANTAGATA, S; Dartmouth College, Long Island University; *scott.santagata@liu.edu*

Morphological Diversity and Phylogeny of Antarctic Bryozoans

Bryozoan diversity in the Southern Ocean is estimated at more than 400 species, the majority of which belong to the cheilostome grade that includes three morphologically rich albeit paraphyletic groups: the Flustrina, the Lepraliomorpha, and the Umbonulomorpha. Although the molecular phylogenetic relationships among many bryozoan species have been explored, the mostly endemic Antarctic bryozoan fauna have not been well represented in these studies. We used SEM and 18S rDNA to explore the taxonomic diversity and evolutionary patterns among bryozoan species collected from the Antarctic shelf of the Palmer Archipelago as well as the Bellingshausen, Amundsen, and Ross Seas. In general, our results support previous morphological-based interpretations of species identities and their macroevolutionary relationships. However, the identities and relationships of some flustrid species are difficult to resolve due to their limited number of taxonomic characters and diverse colony growth forms. Phylogenetic inferences based on transcriptomic datasets are ongoing to resolve these issues.

25-7 SUZUKI, TK; NARO, Japan; *homaresuzuki@gmail.com*

Component-based phylogenetic comparative methods reveal evolutionary pathways toward complex adaptive traits

The evolutionary origin of complex adaptive traits has been a controversial topic in the history of evolutionary biology. Although Darwin argued for the gradual origins of complex adaptive traits within the theory of natural selection, Mivart insisted that natural selection could not account for the incipient stages of complex traits. The debate starting from Darwin and Mivart eventually engendered two opposite views: gradualism and saltationism. Although this has been a longstanding debate, the issue remains unresolved.
Here I review recent findings as a starting point to propose the building logic of complex traits. First, I report that previous studies have already revealed the gradual evolution of several valuable traits (e.g., the giraffe's elongated neck, the asymmetrical eyes of flatfishes, whale baleen, and butterfly leaf wings), which could be explained within the theory of natural selection. Through such a comprehensive survey, I found that these traits satisfy two important characteristics: (1) reducibility into a sum of subcomponents; (2) composability to construct traits from various additional and combinatorial arrangements of the subcomponents. I thus propose the building logic of complex traits, named as reducible-composable multicomponent (rcMC) systems (ref. 1). On the basis of this, I developed an analytical method for exploring evolutionary pathways to build up complex traits, by using component-based phylogenetic comparative methods (*c*-PCMs) based on Bayesian statistics. I used this method and succeeded in revealing gradual evolution of leaf mimicry in *Kallima* butterfly wings (ref. 2). Finally, I use butterfly camouflage patterns and discuss how to decipher structural complexity of morphological traits.

References:

1. Suzuki (2017) J Exp Zool B 328(4): 304-320.
2. Suzuki, Tomita, Sezutsu (2014) BMC Evol Biol 14:229.

72-4 SWAFFORD, AJM*; OAKLEY, TH; UC Santa Barbara; *andrew.swafford@lifesci.ucsb.edu*

Multimodal Sensorimotor System in Unicellular Zoospores of a Fungus

Complex sensory suites often underlie critical behaviors, including avoiding predators or locating prey, mates, and shelter. Multisensory systems that control motor behavior even appear in unicellular eukaryotes, such as *Chlamydomonas*, which are important laboratory models for sensory biology. However, we know of no unicellular opisthokont models that control motor behavior using a multimodal sensory suite. Therefore, existing single-celled model organisms for studying multimodal sensorimotor integration are very distantly related to animals. Here, we describe a multisensory system that controls the motor function of unicellular, zoospores of a fungus. We find zoospores of *Allomyces arbusculus* exhibit both phototaxis and chemotaxis. While swimming, they move towards light and settle on cellulose membranes exuding combinations of particular amino acids. Furthermore, we report that closely related *Allomyces* species do not share this multisensory system. Instead, each respond to only one of the two stimuli detected by *A. arbusculus*. This diversity of sensory modalities within *Allomyces* provides a rare example of a comparative framework that can be used to examine the evolution of sensory systems after the gain or loss of individual senses. Taking advantage of this newfound system, we examine the molecular pathways co-opted during sensory integration within zoospores. The tractability of *Allomyces* and related fungi as laboratory organisms will allow detailed mechanistic investigations into how sensory systems may have functioned in early opisthokonts before multicellularity allowed for the evolution of specialized cell types.

124-1 SWALLA, BJ; Univ. of Washington, Seattle;
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Molgulid Tales

Transcriptome and genome data offer an exciting new approach to examine the origin and evolution of the chordate body plan. Chordate body plan evolution can be studied with two tunicate species with radically different larval body plans that are found sympatrically off the coast of Roscoff, France - the tailed ascidian *Molgula oculata* and the tailless *M. occulta* . Tailed *M. oculata* embryos have forty notochord cells in the center of the tail, muscle cells flanking the notochord in the tail, and in the head is the otolith, a gravity sensory organ. The tailless *M. occulta* does not form a tail in their larval stage, and have only twenty notochord cells that do not converge and extend during larval development. We have sequenced the genomes of these two species and a third species, *M. occidentalis* in collaboration with the Lionel Christiaen lab at NYU, and they are available on Aniseed. We show by transcriptome and in situ hybridization analysis that the notochord gene network is expressed at the right time and place in the tailless *M. occulta* embryos and larvae, although the notochord collapses into a "notoball" near the posterior. We show by transcriptome analyses that the ascidian metamorphosis program begins much earlier in molgulid ascidians, during early development. This radical heterochronic shift has been documented in another tailless ascidian, *M. tectiformis* , and is now reported for three additional species: the tailed molgulid species, *M. oculata* , *M. occidentalis* , and the tailless *M. occulta*. Further functional data is necessary to determine if this pronounced heterochrony is the necessary preadaptation for tailless tadpole to evolve in molgulid ascidians. We've shown that downstream genes become pseudogenes in muscle and the sensory otolith, suggesting that there is an initial upstream hit. This is an excellent model system to study the evolution of gene networks underlying morphology.

9-6 SWANSON, DL*; ZHANG, Y; OBOIKOVITZ, P; AGIN, TJ; Univ. South Dakota, Auburn Univ; *david.swanson@usd.edu*

Seasonal flexibility of metabolism-temperature reaction norms in cold-acclimated house sparrows: A test of the climatic variability hypothesis

Phenotypic flexibility allows animals to match phenotypes to prevailing environmental demands and may improve fitness. The climatic variability hypothesis (CVH) posits that phenotypic flexibility and climatic variability should be correlated, with greater flexibility in more heterogenous environments. In north-temperate climates, climatic variability is greater in winter than in summer, so the CVH predicts that phenotypes should be more flexible in winter than in summer. We tested the CVH by acclimating house sparrows in both summer and winter to 25, 5 and -10 C and measuring basal (BMR) and summit (Msum = maximum cold-induced) metabolic rates before and after acclimation treatments. To examine mechanistic bases for metabolic variation, we measured skeletal muscle and heart masses and pectoralis and heart citrate synthase and β-hydroxyacyl coA-dehydrogenase activities. Summer metabolic rates increased with acclimation for 5 C birds, but not for other groups, and were generally higher after acclimation at cold temperatures than at 25 C. Winter BMR was significantly downregulated at 25 C and nearly so at 5 C relative to -10 C, but Msum was not significantly impacted by acclimation. Masses of pectoralis and heart were upregulated under cold temperatures in summer, but not downregulated under warm temperatures in winter. Catabolic enzyme activities were not clearly related to metabolic variation among acclimation groups. In contrast to predictions of the CVH, these data suggest that metabolism-temperature reaction norms of house sparrows are more prominently upregulated in summer than downregulated in winter and that BMR is more flexible than Msum.

137-7 SWANSON, B*; OSTERSMITH, S; Gonzaga University;
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Dancing Biology: Teaching Evolutionary Biomechanics Through the Art of Dance

Communicating complex scientific ideas to broad audiences continues to be a challenge for those of us in the integrative biology community. Here, we describe a project that uses dance and music to communicate basic ideas about evolution, and more specific conclusions from current evolutionary biomechanics research. We have put together a joint lecture and dance performance designed to fit within the traditional Biology seminar format. The project is a direct collaboration between Biology and Dance faculty, and the performance uses a company of student dancers and a student composer. The performances invite both arts and sciences faculty and students to observe and then interact through a conversation following the performance. We are assessing the impact of the project on audiences and participants. Our expectation is that biologists will learn some biology content, but mostly will gain appreciation for the art as it is expressing familiar ideas. Furthermore, we expect that arts audiences will have access to biological knowledge because of its presentation in the context of performance. Our aspiration is to have a more profound impact on audiences, challenging them to think in new ways. Although challenging, we find that this multidisciplinary approach has the power to engage and deepen understanding for a diverse set of students.

P2-47 SWANSON, RE*; KRAUSE, JS; PEREZ, JH; WINGFIELD, JC; LAU, HJ; MEDDLE, SL; SNELL, KRS; Univ. of California, Davis, Univ. of Edinburgh, Universitetsparken;
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11β-Hydroxysteroid Dehydrogenase Antagonists Administered Centrally and Peripherally Affect Stress Physiology in Wild and Captive White-Crowned Sparrows (Zonotrichia leugophrys gambelii)

The 11-β-Hydroxysteroid Dehydrogenase (11-β-HSD) system has been hypothesized to be a key regulatory step in local signaling and in controlling seasonal changes in corticosterone in free-living birds. 11-β-HSD Type 1 catalyzes local corticosterone production and 11-β-HSD Type 2 catalyzes local deactivation of corticosterone. We tested the hypothesis that 11-β-HSD can affect stress induced corticosterone, and this would provide a means for understanding mechanisms underlying seasonal changes in stress physiology in male white-crowned sparrows (*Zonotrichia leucophrys*). We measured the effectiveness of two separate and specific 11-β-HSD antagonists systemically in the field and centrally into the third ventricle in a laboratory experiment. Inhibition of Type 1 using metyrapone produced mixed results with systemic injections showing measurable decreases with integrated area under the curve (AUC) analyses, while no differences were detected for injections into the third ventricle. Inhibition of Type 2 with diethyldithiocarbamate resulted in elevated corticosterone (AUC) for both systemic and central infusion. Our study suggests plasma corticosterone may be regulated peripherally by Type 1 and centrally by Type 2. As life history stage or other factors could influence 11-β-HSD dynamics throughout the annual cycle, we use caution in this interpretation. Further investigations are needed to fully understand the importance of the 11-β-HSD system in regulating corticosterone in free-living birds.

P3-144 SWENSON, AS*; KIRKTON, SD; WATERS, JS; Providence College, Union College; *aswenso1@friars.providence.edu*

Using X-ray Microtomography to Visualize and Quantify the Nest Architecture of Acorn Ant Colonies

Organismal survival is dictated by a basic need for food, water, and shelter. This is true from bacterial colonies to complex social animals, such as ants and humans. For the acorn ant, *Temnothorax curvispinosus*, a physical nest space is crucial to colony survival. However, it has previously been difficult, if not impossible to visualize and quantify the geometry and spatial organization associated with nest architecture in a non-destructive manner. Modern advancements in imaging technologies make it possible to not only see, but analyze the nest spaces of these ants using x-ray computed microtomography. Acorns were collected in Rhode Island without disturbance by manually observing ants coming and going through microscopic pores in the acorn. These acorns were imaged using the Bruker x-ray microtomography center at Union College, NY. Using Bruker CTAn software, virtual cross-sections of the acorn scans were segmented using regions of interest and binarized to remove artifacts. The resulting binary stacks were then used to generate 3D models and estimate the volume and surface area of the interior nest space with precision in the range of 5%. The three-dimensional models of the internal nest regions were visualized using Bruker CTVol software, revealing a strikingly highly partitioned internal nest geometry. Through computer analysis and modeling, we were able to better understand the physical world in which these acorn ants live, offering insight into their unique natural history and also raising questions about the role that physical and built environments play in shaping social interactions in complex societies.

126-6 SWITZER, CM*; RUSSELL, AL; PAPAJ, DR; COMBES, SA; HOPKINS, R; Harvard Univ., Univ. of Pittsburgh, Univ. of Arizona, Univ. of California, Davis; *callin.switzer@gmail.com*

Pollen out all the stops: How bumble bees modify sonication behavior in response to pollen rewards

A well-studied behavior in bee pollination biology is floral sonication or buzz pollination. During sonication, bees grasp flowers and use vibrations to release pollen. Several researchers have suggested that flowers are tuned to release pollen when vibrated at specific frequencies, but there is little research about how bees respond and learn to modify their sonication behavior in response to pollen rewards. In this study, we built an experimental setup to quickly record and process bumble bees' (*Bombus impatiens*) sonication buzzes. We then used an electronic dispensing system to deliver pollen rewards in real time, based on bees' sonication frequency and amplitude. Using this setup, we were able to gain insight into some of the outstanding questions about floral sonication: 1.) Do the properties of the flower affect sonication frequency and/or amplitudes? 2.) Do bees change their sonication frequency to match the frequency at which the flower releases pollen? 3.) How do bees change their sonication properties when they stop receiving pollen rewards? Using data from over 30,000 sonication buzzes by more than 100 individual bumble bees, we answered some of the questions above. We found that heavy flowers caused a reduction in sonication amplitude, but no change in sonication frequency. We found no evidence that bees learned to change their foraging vibrations, based on the frequency that released the largest amount of pollen. However, we found some evidence that bees follow a predictable behavioral routine when they don't receive a pollen reward. Overall, our approach enabled us to quickly and reproducibly conduct experiments to understand the extent to which and the reasons why bumble bees modify their sonication behavior.

16-6 TAFF, CC*; ZIMMER, C; VITOUSEK, MN; Cornell; *cct63@cornell.edu*

Feather Color Predicts Resilience to Stressors and Social Interactions in Tree Swallows

Signals, resilience to stress, and social behavior can be dynamically linked. For example, social interactions influenced by signals may exacerbate or buffer the effect of stressors, while at the same time stress may alter signals. To date, few studies have examined these possibilities in natural populations. We imposed stressful conditions on female tree swallows by reversibly attaching groups of feathers on each wing during incubation. This treatment reduces flight efficiency, thereby increasing the energetic costs of foraging. We also monitored social activity using a network of RFID units that allowed us to track the identity of every individual that visited each nest box. Relative to controls, stressed females were more likely to abandon their nest during incubation. Overall, females with brighter white breasts were less likely to abandon, but this pattern was only significant under stressful conditions. In addition to being more resilient to stress treatments, females with brighter white breast feathers received more unique male and female visitors at their nest box and made more visits to other active nests in the population, suggesting that these females were more socially active and integrated into the breeding population. In contrast, dorsal coloration did not reliably predict abandonment or social interactions. Taken together, our results suggest that ornaments, resilience, and social behavior are linked. The interaction between treatment and color in predicting abandonment also suggests that the marginal costs of stressors depend on signaling phenotype; differential costs are a key feature of many models of signal honesty, but have only rarely been demonstrated empirically. Ongoing work is focused on elucidating the mechanistic basis for the links demonstrated here and the extent to which causality is multidirectional.

22-1 TAKAGI, D*; HARTLINE, DK; University of Hawaii at Manoa; *dtakagi@hawaii.edu*

Sensing Hydrodynamic Cues and Escaping from Predators: Theoretical Strategies for Swimming Organisms and Robots

The sensory world of free-swimming animals differs radically from that of substrate-dwelling animals. Those carried with the surrounding water and unable to detect its bulk flow have a harder task of detecting objects causing the flow, such as an attacking predator. Cues from local water deformations are nevertheless available to such animals, and reconstructing possible causes of the signals is a fundamental problem in sensory ecology with potential applications to bio-inspired robotics. We present a theory that clarifies what information is contained in disturbances generated by an attacking predator, and we apply it to planktonic copepods that have mechanosensory hairs deployed in a one-dimensional array along a pair of antennules. The theory reveals the presence of "blind spots", potential ambiguities in resolving from which of two sides a predator attacks, and whether it generates a bow wave or suction. Our results show that free-swimming animals perceive an intriguingly ambiguous world, yet they may nonetheless extract sufficient information on the location and imminence of the attack to make informed life-saving decisions in their behavioral reactions.

P1-130 TALAVERA, JB*; COLLOSI , E; ROBERTSON, JM; GRAY, DA; California State University Northridge; *janelle.talavera.220@my.csun.edu*

Are Male Calls Sufficiently Divergent to Promote Reproductive Isolation?-- A Test with Two Parapatrically Distributed Cricket Species

Animal mating signals are typically species-specific and can be important barriers to gene flow among ecologically divergent species. Cricket calls are being well studied in this regard, and species differences in male song and female song recognition are known to be important components of reproductive isolation in certain species-pairs. Here we present data on the songs of two currently undescribed cricket species: *Gryllus* "saxatilis" and *Gryllus* "navajo". These crickets are a closely-related species-pair that are parapatrically distributed in the western USA. *G.* "saxatilis" favors dry rocky slopes throughout California, and in the Mohave, and Great Basin deserts, whereas *G.* "navajo" is restricted to the painted desert region of south-eastern Utah and north-eastern Arizona in areas of red sandstone and reddish badlands clay soils. We analyze calls from multiple populations of both cricket species using the computer program Audacity. The data collected will address whether cricket song is sufficiently divergent to potentially function to promote reproductive isolation between the two species.

35-6 TALBOT, WA*; WOLF, BO; University of New Mexico; *watalbot50@gmail.com*

Avian thermoregulation in the heat: Nocturnal Sonoran Desert birds

In the Sonoran Desert, where diurnal surface temperatures can reach 70°C and air temperatures can reach 50°C, it is imperative for birds to defend body temperatures from lethal hyperthermia. Nocturnal activity buffers nightjars and owls against some temperature extremes. When environmental temperatures exceed body temperature, evaporative cooling is essential but carries the risk of dehydration. During the breeding season, Lesser Nighthawks (*Chordeiles acutipennis*) and Common Poorwills (*Phalaenoptilus nuttallii*) nest on the soil surface and must cope with very high diurnal temperatures, while Western Screech-owls (*Megascops kennicottii*) and Elf Owls (*Micrathene whitneyi*) use cavities in trees and cacti for nesting. As a consequence, owls and nightjars are subjected to very different diurnal heat loads, which affects their costs of thermoregulation and ability to balance their water budgets. More frequent and severe heat waves will raise nocturnal temperature minima and may affect activity periods or costs. An understanding of the thermoregulatory capacity across species may offer some prediction of their ability to adapt to changes in climate. We measured resting metabolic rates, body temperature, rates of evaporative water loss and thermal tolerance using flow-through respirometry. Nightjars and owls show some similarities as well as some differences in their capacities for thermoregulation in the heat. Overall, nightjars tolerate air temperatures as high as 64°C and owls, in contrast, showed thermal tolerances more similar to passerine birds (ca. 50°C).

P2-273 TALLEY, JL*; THOMPSON, J; Air Force Research Laboratory, University of Florida; *jennifer.talley.1@us.af.mil*

Scene Statistic Effects on Sensor Stabilization in the Damselfly Ischnura ramburii

Predatory insects are able to perform advanced flight and attack tactics with some of the most simplistic and compact optic systems on the planet. Insects possess a low-resolution optical system that requires little image processing to utilize these performance capabilities making them ideal subjects for bio-inspired technology development. We tested which of two visual scene factors affect the gaze stabilization of a damselfly species, *Ischnura ramburii. More specifically, the goal of this research was to pin-point the contrast and spatial frequency values in a projected, rolling scene that the insects responded to most robustly. In order to determine which scene statistics provoked the best responses, each specimen tested was exposed to multiple scenes with various combinations of contrast and spatial frequency values. The responses were recorded and changes in response robustness were observed.*

106-1 TAMONE, SL*; LEVY, T; BOWER, E; SAGI, A; University of Alaska Southeast, Ben Gurion University of the Negev; *sltamone@alaska.edu*

Expression of vitellogenin (Vg) gene from the hepatopancreas and gonad of the protandric shrimp Pandalus platyceros

The Northern spot prawn (*Pandalus platyceros*) is a commercially important shrimp species in Southeast Alaska that has an interesting life history which presents challenges for its effective management. *P. platyceros* is protandric and demonstrates sequential hermaphroditism. As this shrimp matures, it transforms from a small functional male to a much larger functional female. During its life history, the male shrimp undergoes multiple molts as a male and at least one transitional prior to becoming a functional female. Our study objectives were to characterize the vitellogenin (Vg) gene from *P. platyceros* and to study its expression in male, transitional, and female shrimp tissues. Shrimp of each life history were collected during the Alaska Department of Fish and Game shrimp survey and maintained at the University of Alaska marine laboratory in flow-through sea water. Life history stages were confirmed visually from the distinct morphology of the second pleopod. The (*Pp*Vg gene was identified from the hepatopancreas using primers designed from the congeneric species, *P. hypsinotus*. The gene was partially sequenced using RACE PCR and cloning techniques. Spatial expression of *Pp*Vg was determined from tissues (hepatopancreas, ovary, muscle, and heart) from mature female *P. platyceros*. Expression of the gene was determined from total RNA extracted from the hepatopancreas and gonad of males and transitional shrimp. We found *Pp* Vg expression in the hepatopancreas and the gonad of the transitional and the female life history stage but not in males. Future studies will use qtPCR to measure the temporal expression or *Pp*Vg in transitional shrimp to better understand physiological changes associated with sexual differentiation.

P1-112 TAN, F*; JEW, B; PERRY, K; HENRY, J; LYONS, D; Univ. of California, San Diego, Univ. of Illinois at Urbana-Champaign, Univ. of Illinois at Urbana-Champaign; *fhtan@ucsd.edu*

Cellular and molecular control of axial elongation in a spiralian embryo, Crepidula fornicata

During embryogenesis, animal embryos often transition from a sphere of cells to a pill-shaped stage as they elongate along the anterior-posterior axis. This process of axial elongation is deeply conserved amongst Bilateria, occurring before divergent morphologies arise in embryogenesis. Yet, the cellular and molecular mechanisms that control it are not well-understood among a large and morphologically diverse branch of animals, the Spiralia (including annelids, molluscs, nemerteans). We are using the slipper snail Crepidula fornicata as a representative spiralian to study the mechanisms controlling axial elongation. A common hypothesis for axial elongation among spiralians involves differential proliferation on the dorsal side of the embryo. However, this was not observed in Crepidula fornicata. Instead, we hypothesize that cellular re-arrangement is primarily responsible for axial elongation. To better understand the molecular basis for axial elongation in Crepidula fornicata, pathways involved in early development were inhibited and it was found that inhibition of the JNK pathway resulted in a noticeable phenotype. Since previous work has shown that JNK interacts with the non-canonical Wnt pathway to regulate morphogenesis in different model organisms, including Drosophila and Xenopus, expression patterns for genes involved in the non-canonical Wnt pathway were obtained through in situ hybridization. Through studying axial elongation in this new gastropod model, we hope to contribute to understanding early development by characterizing morphogenetic processes not observed in more traditional model organisms.

101-7 TANG-MARTINEZ, Z*; BRAUDE, S; University of Missouri-St. Louis , Washington University ; *zuleyma@umsl.edu*

Re-examining the Testosterone and Immunosuppression Hypothesis: Why Some of the Evidence Casts Doubts

In 1992, Folstad and Karter published the immunocompetence handicap hypothesis, suggesting that testosterone not only influences male sexually-selected traits, but also results in immunosupression, hence indicating a handicap; only those individuals with superior immune systems can afford the cost of producing and maintaining elaborate sexually-selected traits, while simultaneously being able to fight off parasites and pathogens. We (Braude et al., 2009) challenged this idea by proposing the immunoredistribution hypothesis. We argued that, under stressful conditions, the immune cells in the blood migrate to more vulnerable areas of the body where they are most needed, such as to the skin when there is a danger of superficial injuries. The loss of immune cells in the blood can then lead to the mistaken conclusion that immunosuppression has occurred. The general view, however, continues to be that testosterone inevitably suppresses the vertebrate immune system. Here we examine and review empirical data showing that, at least in some species, there is scant unequivocal evidence that testosterone is immunosuppressive. Studies on parasites, testosterone, and immunity do not always support the hypothesis. Some meta-analyses likewise have failed to find strong support. Other studies find that results obtained under natural, field conditions may differ (less likely to show immunosupression) compared to those obtained in the lab. Moreover, testosterone may have indirect effects on body condition, or other steroid hormones, that can confound the interpretation of results. These disparate threads of evidence suggest that the widely-held belief that testosterone is unquestionably immunosuppressive needs to be re-evaluated.

59-1 TANNER, R.L.*; SOUSA, W.P.; STILLMAN, J.H.; Univ. of California, Berkeley; Romberg Tiburon Center for Environmental Studies, San Francisco State Univ., Univ. of California, Berkeley; *rtanner@berkeley.edu*

Transgenerational thermal tolerance plasticity may play a role in maintaining seasonal differences between populations of Phyllaplysia taylori with climate change

Zostera marina eelgrass beds in San Francisco Bay fluctuate seasonally in temperature, light availability, nutrients, and invertebrate community composition. A significant invertebrate grazer in this community, the sea hare *Phyllaplysia taylori*, promotes eelgrass health by clearing blades of epiphytic material. *P. taylori* has two generations per year that differ in size, lifespan, and thermal performance. One generation matures in the early spring and the other matures in late summer. Thermal performance of the summer generation peaks at lower temperatures than in the spring generation. In this study, parents of the summer generation were acclimated at temperatures representing current winter (13ºC), current summer (17ºC), and future summer (21ºC). Embryos from parents at all three temperatures were reared in a split-brood orthogonal design, raised at all three temperatures with or without an acute heat shock (30ºC) during early embryonic development. Embryo size, density, and survival were assayed. 17ºC had the highest survival across parental and developmental exposures. 21ºC resulted in lower survival for all broods except when this was the parental acclimation temperature. There were no significant effects of the acute heat shock on any treatment group. Conditions that resulted in the lowest embryonic survival experienced the most likely future climate scenario (parental rearing at 21ºC and embryonic development at 13ºC). Therefore, increased habitat temperatures are likely to reduce survival of these sea hares, diminishing their ecological influence on eelgrass.

P2-266 TANNER, MK*; SANDERS, EJ; IBRAHIM, O; BUBAK, AN; LAILVAUX, S; SWALLOW, JG; GREENWOOD, BN; University of Colorado Denver, University of Colorado Anshutz Medical Campus, University of New Orleans; *margaret.tanner@ucdenver.edu*

Effects of Physical Activity on Behavior in House Crickets

Physical activity in mammals has been shown to modulate behaviors important for survival by acting on monoamine neurotransmitters, such as dopamine and norepinephrine. Monoaminergic systems are present in invertebrate species; however, little is known about the effects of physical activity on monoamine-dependent survival behaviors in non-mammalian species. In the common house cricket *Acheta domesticus*, the norepinephrine analog octopamine is involved with experience-dependent changes in survival behaviors, such as aggressive behavior and bite-force. Here we investigated the effects of physical activity on bite-force in male and female common house crickets. Crickets were exercised by placement in rotating tubes at various speeds (160 cm/min, 260 cm/min, 360 cm/min) and duration. Control crickets were placed in stationary tubes for equal amounts of time. Initial results reveal that physical activity at a rate of 260 cm/min optimally increases bite force. The duration of physical activity that optimally increases bite force is still being analyzed. Follow-up studies will incorporate the chosen speed and duration to verify these initial results and determine the effect of physical activity on monoaminergic systems in house crickets.

132-8 TAO, Y; KAINAN, H*; DI SATO, V; YUFEI, H; ZIYU, R; LAUDER, G; WEN, L; Beihang University, Harvard University, Harvard University; *liwen@buaa.edu.cn*

A Bioinspired Robotic Fish Fin with Mechanosensensation Using Conductive Liquid-Metal-Infused Soft Actuators

Fish fins function not only in propulsion, but also to provide sensory input from the environment. Fish can sense fin ray bending using intrinsic fin sensors, and alter their behaviors based on sensor inputs. Inspired by the mechanosensory system of fish fins, we developed a bioinspired robotic prototype that integrates both soft sensing and locomotor capability. First, we used multi-material 3D printing to manufacture a soft-rayed fin mechanism which allows the fin to be erected/folded, and flap laterally. Then we fabricated soft sensors by using hyperelastic silicone elastomers (modulus: 55 kPa) with a spiral-pattern micro-channels which were infused with conductive liquid metal (eutectic gallium indium). The soft sensor possesses a circular shape, and is capable of detecting sensitive contact pressure along the normal axis. We integrated these soft sensors with an array of fiber-reinforced soft actuators that mimic the dorsal/anal inclinator and erector/depressor fin muscles. The fin prototype demonstrates the capability of detecting fin ray bending as well as differentiating the direction of external force imposed on the fin rays. We tested the fin prototype in a water tank that can generate programmable flow speeds, and simultaneously recorded the outputs of the soft sensors as well as high-speed images of fin deformation. Finally, we examined the sensory output of the bioinspired soft dorsal/anal fins on an undulatory fish robot at different body undulatory frequencies and amplitudes. Bioinspired fins with mechanosensory input may provide a new approach for underwater robotics with a proproceptive feedback capacity for navigating through the cluttered environments.

S1-9 TARHAN, LG*; DROSER, ML; GEHLING, JG; Yale University, University of California, Riverside, South Australian Museum and University of Adelaide; *lidya.tarhan@yale.edu*

Ecological Innovation in the Late Ediacaran

The Ediacara Biota, Earth's earliest communities of complex, macroscopic, multicellular organisms, appeared during the late Ediacaran Period, just prior to the Cambrian Explosion. Ediacara fossil assemblages consist of exceptionally preserved soft-bodied forms of enigmatic morphology and affinity which nonetheless represent a critical stepping-stone in the evolution of complex animal ecosystems. The Ediacara Biota has historically been divided into three successive Assemblages—the Avalon, the White Sea and the Nama. Although the oldest (Avalon) Assemblage documents the initial appearance of several groups of Ediacara taxa, the two younger (White Sea and Nama) Assemblages record a particularly striking ‘second wave' of ecological innovations, including the rise of diverse Ediacara body plans—in tandem with the appearance of bilaterian animals—as well as the emergence of novel ecological strategies such as movement, sexual reproduction and biomineralization and the development of dense and heterogeneous benthic communities. Intriguingly, many of these ecological innovations appear to be linked to ‘matground' adaptations tied, in turn, to the prevalence of organically bound substrates in shallow and energetic marine settings. Moreover, although these distinctive ecological strategies were implemented by Ediacara taxa of unresolved affinity, they are also characteristic of younger animal-dominated communities of the Phanerozoic. The late Ediacaran emergence of these strategies may therefore have been pivotal to the subsequent radiations of the Cambrian. In this light, the Ediacaran and Cambrian Periods, although traditionally envisioned as separate worlds, may have been part of an ecological and evolutionary continuum.

99-5 TARRANT, AM*; HELM, RR; REITZEL, AM; RIVERA, HE; Woods Hole Oceanogr. Inst., UNC Charlotte; *atarrant@whoi.edu*

Daily Environmental Cycles Entrain Robust Gene Expression Patterns in the Sea Anemone Nematostella vectensis

Cnidarians exhibit diel rhythms including cycles in locomotor activity, tentacle extension, and spawning. Behavioral and molecular studies conducted in corals and the anemone *Nematostella vectensis* suggest the presence of an endogenous circadian clock. *Nematostella* inhabits shallow estuarine habitats that can experience strong diel and/or tidal cycles in light, temperature and water chemistry, so we sought to characterize rhythmic gene expression within *Nematostella* exposed to natural field conditions. Anemones from the lab were incubated within mesh cages in a tidal pool in Sippewissett Marsh, the site from which the lab population was derived. After two weeks, animals were recovered, sampled every two hours over a 24-hour period (12-hour light/dark), and characterized using RNA-seq. Rhythmic genes were identified using the R-package JTK_CYCLE. These data indicate that a large number of genes undergo a diel cycle in expression (3813 genes/22.7% of the filtered transcriptome with an adjusted p-value <0.05), compared with only 365 genes exhibiting a 12-hour tidal cycle. Many genes previously identified as cyclic in *Nematostella* (Clock, Hes/Hey-like, heat shock proteins, protein disulfide isomerase) were confirmed as cyclic in this study. Surprisingly, the rhythmic genes were heavily biased toward daytime peaks in expression. In addition, approximately 160 of the rhythmic genes have also been shown to be directly inducible by UV exposure in *Nematostella*. This study indicates that natural field conditions stimulate large daily cycles in gene expression, which are greatly reduced under more constant laboratory conditions used in previous studies. Despite the burrowing behavior of the anemones, light appears to remain an important driver of gene expression and physiology.

8-6 TASSIA, MG*; HALANYCH, KM; Auburn University; *mgt0007@auburn.edu*

State of the Imm-Union: Gaps and ambiguity in the evolution of metazoan immune systems

In this presentation, we will overview knowledge of metazoan immunity evolution in the context of animal diversity and phylogeny outlined below - discussing trends in methodology and vital gaps in knowledge on conserved and lineage-specific cellular/molecular immune systems. Animals persist in a diverse array of environments laden with pathogenic microbes. To combat infection, metazoans have evolved an array of molecular pathways and cell-types dedicated to recognizing and disposing of pathogenic particles. Coinciding with the evolution of multicellularity in Metazoa, *bona fide* immunity has been hypothesized to be the result of cooption as a function of the novel requirement for distinguishing between self and non-self (i.e., allorecognition) at the base of the animal tree of life. Even in the earliest diverging animal lineages (i.e., Ctenophora, Porifera, Placozoa, and Cnidaria, respectively), immunity-associated cell types and conventional innate immunity signaling pathway components are identifiable, though with varying degrees of similarity to those in well-described model systems (e.g., Mouse and Human). Within Bilateria, canonical innate immunity pathways are well-recognized and genome analyses indicate several lineage-specific expansions and retractions which have been hypothesized to be a result of invertebrate's absolute reliance on an immune system which offers no plasticity over an individual's lifetime. These hypotheses are made in the context of immune systems predating the emergence of vertebrate *immunological memory*, or "true" adaptive immunities. However, the reliance of comparisons to biomedical model vertebrate systems results in inaccurate assessments of "directional" immunity evolution towards vertebrate-like complexity - perhaps hindering understanding of true immune complexity across Metazoa.

P3-40 TAYLOR, HA*; ZHANG, Y; KASH, M; KAVAZIS, AN; ROBERTS, M; HOOD, WR; Auburn University; *hat0008@auburn.edu*

Response of Hepatocytes to ROS Exposure: Temporal Variation in Oxidative Stress Response Signaling Pathways

When produced in excess, reactive oxygen species (ROS) can cause damage that has lasting impacts on cellular performance. However, when cells are exposed to modest levels of ROS, the cells upregulate signaling processes that improve cellular performance. In a prior study, we induced ROS emission in mice via X-irradiation and found that 24 hours post exposure, ROS production and oxidative damage increased, but 10 days after X-irradiation exposure both ROS production and oxidative damage levels fell to below non-irradiated control levels. This finding suggests that despite initial damage, cells may experience improved condition following a modest oxidative event. The aim of the current study is to deduce the mechanisms responsible for this hormetic effect. We employed a cell culture model, and our goal was to determine if AML12 mouse hepatocytes display a response to ROS that is comparable to liver cells of mice exposed to X-irradiation. Mitochondrial function and ROS emission of hepatocytes were measured 1, 24, 48, and 72 hours after X-irradiation. The levels of oxidative damage, antioxidants, and select transcriptional factors that are targets of ROS signaling, including Nrf-2, PCG-1α , and PPAR-γ were measured. Results for radiated cells and non-irradiated control cells will be described. Future studies will identify the pathways response for the hormetic effect by up- and down-regulating identified candidate genes.

P1-171 TAYLOR, RE*; RESNIKOFF, A; PECHENIK, JA; PIRES, A; Dickinson College, Tufts University; *pires@dickinson.edu*

Effects of Acidification and Salinity Stress on Development in Larvae and Juveniles of the Marine Gastropod Crepidula fornicata

The earth's oceans are becoming more acidic due to absorption of atmospheric CO_2. Ocean acidification (OA) decreases the concentration of carbonate ions in seawater, and may impose increased energy costs on organisms that deposit calcium carbonate shells and skeletons. Larval stages of these organisms are especially vulnerable to combined stresses of OA, low salinity, and nutrition, which may have a common energetic basis. Our study species, the caenogastropod *Crepidula fornicata*, is widely distributed in temperate near-shore environments including estuaries where pH and salinity vary greatly. We investigated how acidification and low salinity affect larval growth, induction of metamorphosis, and juvenile growth. Larvae and juveniles were cultured at 4 combinations of salinity (20 or 30 ppt) and pH (7.6 or 7.9). At high salinity, larvae grew at similar rates at pH 7.6 and 7.9. However, larvae grew more slowly at low salinity, and the effect of salinity dilution on larval growth was magnified by lower pH. Few of the larvae in the combined low pH/low salinity treatment became competent for metamorphosis, but larvae in other treatments metamorphosed at high frequency in response to elevated [K+] by 15 days after hatching. In contrast to larvae, juveniles grew at similar rates at pH 7.6 and 7.9 within low as well as high salinity treatments. Juveniles generally grew faster at high salinity regardless of pH. However, juveniles that had been reared at low salinity as larvae grew faster at low salinity as juveniles during the first 4 days after metamorphosis, suggesting a carryover effect of larval acclimation to low salinity. (Supported by NSF 1416690.)

P3-239 TAYLOR, L*; FINNEGAN, S; University of California, Berkeley; *larry.taylor@berkeley.edu*

Isotopic Analysis of Fossil Whale Barnacles to Reconstruct Prehistoric Whale Migration: Preliminary Results

Migration is a defining feature of modern mysticete whale ecology, but the prehistoric history of this behavior remains largely unknown. Understanding when migration became established and whether migration paths have been stable through time could yield valuable insights into mysticete evolutionary history, and may also have implications for crafting conservation strategies. The fossil record of coronulids - the epizoic barnacles that live attached to the skin of some mysticetes - offers a potential proxy for reconstructing prehistoric migration routes. Killingley (1980) demonstrated that the oxygen isotope profiles of modern-day gray whale barnacles (*Cryptolepas rhachianecti*) preserve a high-resolution geochemical record of a whale's annual migration path, and we have demonstrated that isotopic analysis of modern-day humpback whale barnacles (*Coronula diadema*) can also be used to reliably reconstruct whale migration paths. Here we present initial results from ongoing analyses of Plio-Pleistocene specimens of both *Coronula diadema* and *Cryptolepas rhachianecti*. Calcite preservation is in most cases excellent, and diagenetic alteration can be diagnosed by textural and trace metal analysis. Oxygen isotope profiles recovered from well-preserved specimens reveal patterns suggesting that Plio-Pleistocene whales were undertaking migrations similar to those of today. Combining barnacle isotope profiles with local proxies and oceanographic models may ultimately enable the reconstruction of prehistoric whale migration pathways, allowing us to better understand the role of migration in mysticete evolutionary history and the behavioral stability of migration across varying climate states.

85-5 TAYLOR-BURT, KR*; GILLESPIE, K; BIEWENER, AA; Harvard University; *karitaylorburt@fas.harvard.edu*

Aquatic takeoffs require faster leg muscle contractions than terrestrial takeoffs in mallard ducks

Mallard ducks are capable of nearly vertical takeoffs from both aquatic and terrestrial environments. The leg provides propulsive force for takeoffs in both media, in part, through ankle extension; however, force production differs between these media, creating an interesting challenge for leg muscle function. On land, force production depends on ground reaction forces; while in water, hydrodynamic force depends on the square of propulsive movement velocity. Correspondingly, we previously found angular velocity at the ankle is twice as fast for aquatic (991 ± 335 °/s) than terrestrial (487 ± 211 °/s) takeoffs. The gastrocnemius is a pennate muscle that drives ankle extension in ducks. Pennate muscles can change overall shortening velocity by changing velocity along the fascicle and through pennation angle changes in response to changes in load (i.e., variable gearing). We used sonomicrometry to measure fascicle length changes in the gastrocnemius during aquatic (n=5) and terrestrial (n=9) takeoffs in 4 mallard ducks. Gastrocnemius fascicle shortening velocity is nearly 3 times higher during aquatic (4.2 L/s) vs. terrestrial takeoffs (1.4 L/s), due to both larger excursions and shorter durations. We calculated pennation angle for a subset of the trials (aquatic: n=3, terrestrial: n=7) and found aquatic takeoffs involve similar pennation angle changes (4.0 ± 0.9 °) compared to terrestrial takeoffs (4.1 ± 1.9 °). These data demonstrate that shortening velocity changes substantially depending on the takeoff medium, highlighting the challenge for muscles to generate movement in multiple media. Fascicle shortening velocity, not changes in pennation angle excursion, drives the gastrocnemius's contribution to faster leg motions during aquatic takeoffs.

9-1 TELEMECO, R.S.*; GANGLOFF, E.J.; California State University Fresno, Iowa State University; *telemeco@csufresno.edu*
High Temperature, Oxygen, and Performance: Insights from Reptiles and Amphibians
Much recent theoretical and empirical work has sought to describe the physiological mechanisms underlying thermal tolerance in animals. Leading hypotheses can be summarized as either subcellular components (i.e. proteins or membranes) or organ systems (i.e. oxygen and capacity limited thermal tolerance) failing at high temperatures. Nonetheless, a general framework has remained elusive. We leverage decades of research on the physiology of ectothermic tetrapods, amphibians and non-avian reptiles, to address these hypotheses. Available data suggest both mechanisms are important. Thus, we propose an integrated framework, which we call Broad-sense Oxygen and Capacity Limited Thermal Tolerance (Broad-sense OCLTT). This framework explains how subcellular and organ system failures interact to limit performance and set tolerance limits at high temperatures. We further integrate this framework with the thermal performance curve paradigm commonly used to predict the effects of thermal environments on fitness. The Broad-sense OCLTT framework appears to successfully explain diverse observations in reptiles and amphibians and makes numerous predictions that remain untested. We hope that this framework spurs further research in diverse taxa and facilitates mechanistic forecasts of biological responses to climate change.

61-7 TEMEL, FZ*; SUTTON, GP; PATEK, SN; WOOD, RJ; Harvard Univ., MA, Univ. of Bristol, Bristol, Duke Univ., NC; *fztemel@seas.harvard.edu*
Trap-jaw ant-inspired jaw-jumping mechanisms explore energetics of insect jumping
Jumping locomotion has been of great interest in mobile robotics to help robots overcome the obstacles that are higher than the robot's center of mass. In nature, many animals use jumping to travel great distances, escape from predators, or catch prey. Small-scale insects have developed various jumping mechanisms and strategies such as composite bows, mechanical linkage systems, and gear trains. In contrast to many legged jumping insects and the robots they have inspired, trap-jaw ants often jump with their jaws. *Odontomachus brunneus* (mass: 6 mg) close their mandibles with extreme velocities, allowing them to jump with take-off velocities of 4.0 m/s, accelerations of 6,100 m/s^2 and a power density of 88,000 Watts per kg of muscle. Here we present a trap-jaw ant-inspired mechanism, designed and manufactured to investigate the energetics of this highly dynamic system and is twice the length scale of a trap-jaw ant head, measuring 2mmX4mmX6mm. To manufacture this mechanism with actuation, latch, and energy storage elements at the millimeter scale, we employ the techniques of smart composite microstructures to manufacture and assemble the multilayer device. The main structural material in this mechanism is shape memory alloy, which serves as the revolute joint, energy storage element, and actuator through heating. We selected stainless steel for mandibles to increase the strike force in jumping. Preliminary experiments show that the 58 mg mechanism can perform a vertical jump up to 75 times its body length, with a jumping velocity of 3 m/s, acceleration of 6,000 m/s^2 and a power density of 9,000 W/kg. Mandible velocity and acceleration while pushing against the ground are measured as 2,4 m/s and 9×10^3 m/s^2, respectively.

P3-277 TEZAK, BM*; SIFUENTES, I; WYNEKEN, J; Florida Atlantic Univ.; *btezak@fau.edu*
Molecular mechanisms behind sex determination in turtles: is moisture playing a role?
Many species of turtles exhibit temperature dependent sex determination (TSD). In TSD species, the differentiation of gonads into ovaries or testes appears to depend on egg incubation temperature during a period of embryonic development known as the thermo-sensitive period (TSP). In response to key environmental variables, a network of differential genetic and cellular responses lead to the formation of ovaries or testes. In addition to temperature, experimental studies suggest that moisture may influence sex determination in a variety of turtle species. In this study, we used the freshwater turtle *Trachemys scripta* to test the effects of both temperature and moisture on expression patterns of genes that likely play an important role both in sex determination (CIRBP, WT1, DMRT1) and later in sex differentiation (*sox9*, aromatase). Eggs were incubated at male promoting temperatures and moderate moisture until the beginning of the TSP and were then split into four different temperature and moisture treatments. Half of the eggs in each treatment were sacrificed ~48h after the treatment shift to collect gonads and identify differences in gene expression early during sex determination. The remaining embryos were sacrificed after completion of the TSP for collection of differentiated gonads; one gonad from each embryo was preserved for gene expression analysis and the other was prepared for histological identification of sex. Here, we aimed to expand our understanding of the mechanisms underlying TSD, particularly the expression of the initial genes that respond to an environmental cue and signal the development of an ovary vs. a testis. Integrating the processes from the molecular mechanism to an organism's sex and to a population's sex ratios at ecologically relevant scales could help fill a long-standing gap in the understanding of how TSD species react to dynamic environments.

28-7 THATJE, S; University of Southampton, National Oceanography Centre Southampton ; *svth@noc.soton.ac.uk*
Transitions from shallow to deep-water life: physiological adaptations to life under hydrostatic pressure
Recolonisation of the deep-sea by shallow water organisms following catastrophic climatic event has taken place on several occasions of the geological past. At shorter time scale, a shift in the distribution of species is of great importance as a response for species facing climate change. Many studies have focussed on the capacity of marine ectotherms to shift their ranges latitudinally in response to current ocean-surface warming. Bathymetric range shifts offer an important alternative; yet hardly any relevant data exist. Hydrostatic pressure (HP) and temperature have wide ranging effects on physiology, importantly acting in synergy thermodynamically, and therefore represent key environmental constraints to bathymetric migration. Here, I synthesise data from recent studies on the thermal scope, thermal and hydrostatic pressure acclimation, and transcriptional regulation in a shallow-water marine crustacean (Palaemon varians) to establish the potential physiological limit to bathymetric migration by shallow-water fauna. Observed changes in gene expression are indicative of cellular macromolecular damage, disturbances in metabolic pathways, and a lack of acclimation after prolonged exposure to high HP. These effects appear less deleterious at higher temperatures, and are exacerbated at lower temperatures. These data have important implications for our understanding of the potential for marine ectotherms to undergo climate-driven bathymetric range shifts.

P2-140 THATJE, S*; SMITH, KS; MCCLINTOCK, JB; MOKSNES, PO; HAVENHAND, JN; ARONSON, RB; University of Southampton, UK, University of Exeter, UK, The University of Alabama at Birmingham, Alabama, University of Gothenburg, Sweden, Florida Institute of Technology; *svth@noc.soton.ac.uk*

Bathyal king crabs face no thermal barrier to emergence in Antarctica

The Southern Ocean's cold-water environment has excluded durophagous predators from the Antarctic seafloor for millions of years. Rapidly warming seas off the western Antarctic Peninsula (WAP) could now facilitate their return to the continental shelf. King crabs (Lithodidae) living in reproductively viable populations on the adjacent slope are among the likely first arrivals. We used underwater imagery to survey slope-dwelling populations of the lithodid crab Paralomis birsteini and their prey off Marguerite Bay, WAP, where lithodid densities averaged 4.28 ind·1000 m-2 at mid-slope depths of 1100-1499 m (range 3.44-5.01 ind·1000 m-2), and off Anvers Island, where densities were lower, averaging 2.06 ind·1000 m-2 at the same depths (range 0.66-3.27 ind·1000 m-2). Analysis of the gut contents of P. birsteini suggested that they are generalized predators of invertebrates. Three commonly eaten, skeletonized taxa—ophiuroids, echinoids, and gastropods—were negatively associated with P. birsteini off Marguerite Bay, where lithodid densities were higher, but not off Anvers Island. With water temperatures on the outer shelf (400-500 m depth) already warm enough, and with sufficient prey densities in the outer-shelf environment, there appear to be no barriers to prevent the lithodids from expanding upward and emerging on the outer shelf. However, temperatures remain too cold for them to survive in shallow, coastal environments. Lateral or vertical range expansions of P. birsteini could substantially reduce populations of their prey, overprinting the direct impacts of rising temperatures on the distribution and diversity of the shelf benthos.

102-2 THAWLEY, CJ*; KOLBE, JJ; University of Rhode Island; *cthawley@uri.edu*

When the Lights Go Up in the City: Artificial Light at Night Impacts Reproduction in Brown Anoles (Anolis sagrei)

Anthropogenic changes including accelerating urbanization have important costs and consequences for affected organisms. As human-impacted environments increase, artificial light at night (ALAN), an evolutionarily-novel stressor, affects many species worldwide. A growing body of research shows that ALAN can impact physiological functions, survival, and reproduction of diverse taxa, yet we lack a strong understanding of how this form of global change affects reptiles. Anoles are adapted to specific photic environments and some species, including the brown anole (*Anolis sagrei*), thrive in cities where ALAN is prevalent. Previous research shows that photoperiod may drive onset of reproduction in brown anoles and that lighting alters nocturnal activity in anoles, suggesting that ALAN could impact reproduction in this species and serve as a novel stressor. We captured brown anoles at the beginning of the breeding season from remnant forest habitat in the Miami metropolitan area and exposed them to natural light cycles or artificial light at night in the lab. Exposure to ALAN increased growth and caused female anoles to begin egg-laying at earlier dates. ALAN did not impact number of eggs produced or size and viability of eggs or offspring, but did affect reproductive investment by smaller females and altered stress levels in anoles. As the human populations grows and urban areas expand, artificial lighting is likely to impact many organismal traits, including reproduction, in a variety of organisms.

P2-223 THERIAULT, J*; BAHLMAN, J; SHADWICK, R; ALTSHULER, D; Univ. of British Columbia, Vancouver; *jtheriau@zoology.ubc.ca*

Work loop dynamics of the pigeon (Columba livia) humerotriceps and its potential role for active wing morphing

Avian wings change shape during the flapping cycle due to the activity of a network of intrinsic wing muscles. One control aspect is elbow joint motion, which relates to wing folding for the upstroke and re-expansion for the downstroke. Muscle anatomy suggests that if the muscles are actuating then the biceps flex the elbow, and the two heads of the triceps, the humerotriceps and scapulotriceps, extend the elbow. Elbow angle control is uncertain as motor elements can have diverse functions such as actuators, brakes, springs, and struts, where specific roles and their magnitudes depend on when muscles are activated in the contractile cycle. The wing muscles best studied during flight are the elbow muscles of the pigeon (*Columba livia*). *In vivo* studies during different flight modes show variation in strain profile, activation timing and duration, and in contractile cycle frequency of the humerotriceps. This variation suggests that the pigeon humerotriceps may alter wing shape in diverse ways. To test this hypothesis, we developed an *in situ* work loop technique to measure how activation duration and contractile cycle frequency affected muscle work and power across the full range of activation onset times. The humerotriceps produced mainly net negative power, likely due to relatively long activation durations, indicating that it absorbs work, but the work loop shapes also suggest varying degrees of elasticity and resistance. Although we were not able to examine the effects of variation in strain profile, our results, when combined with previous *in vivo* studies, indicate that the humerotriceps can dynamically shift among roles of brake, spring, and strut, based on activation properties that vary with flight mode.

140-5 THEUERKAUFF, D*; LAMBERT, S; A. RIVERA-INGRAHAM, G; MERCKY, Y; SUCRE, E; LIGNOT, JH; University of Montpellier and University of Mayotte, University Center of Mayotte, University of Montpellier, University of Mayotte, Universityof Mayotte, University of Montpellier; *dimitri.theuerkauff@umontpellier.fr*

Mangroves as biofilters: how do crabs physiologically react to enhanced ammonium inputs?

Legally or not, mangroves have been used as biofiltering systems of wastewater (WW) effluents in tropical countries. Although this release enhances the ecosystem functioning (e.g. primary production), previous studies showed that WW discharges impact crab species, which are key ecosystem engineers. The WW impact occurs at different scales ranging from population effects down to individual and cellular damage. One of the major pollutants in WW effluents is ammonia, known to be toxic for many crustaceans. To better understand the effects of WW-released ammonia on mangrove crabs, this study focused on a mangrove forest located on the island of Mayotte (Indian Ocean). This experimental site is used to monitor the ecological and physiological effects of daily WW discharges. In the control area, NH_4-N concentration is about 0.11 mgL^{-1}, but for the impacted area, values present a high variability (3.3 to 75 mgL^{-1}). In laboratory condition, the physiological effects of ammonia concentrations up to 80 mgL^{-1} on the Spider crab (*Neosarmatium meinerti*) were determined with a focus on osmoregulation, excretion and energy metabolism (animal respiration rates, mitochondrial activity in the gills). NH_4-N at 2.5 and 80 mgL^{-1} induced enzyme activity alterations for the Na^+/K^+- and H^+-ATPase pumps, especially in the anterior gills. However, hemolymph osmotic pressure is maintained constant even if ammonia accumulates at high exposure. Also, respiration rates is increased with ammonia exposure but mitochondrial activity tends to decrease in the anterior gills. These results confirm the negative effects of ammonia on crab physiology. This can at least partially explain the ecological changes observed in the field.

P2-134 THILL, VL*; TEGLAS, MB; FELDMAN, CR; Univ. of Nevada, Reno; *vthill@nevada.unr.edu*

You Lose, Spidey! Evidence for Resistance to Black Widow Spider Venom in Sympatric Lizards

Black widow spiders (*Latrodectus*) have evolved a potent venom (Latrotoxin, or LTX) that is effective against a wide range of prey, including small vertebrates. While the effects of LTX on mammals are well understood, the effects on reptiles have never been investigated. Lizards are often major predators of spiders, and at least two lizard species (*Elgaria multicarinata* and *Sceloporus occidentalis* are broadly syntopic with, and prey upon, *Latrodectus* in the western US. We sought to determine whether these lizards possess resistance to LTX. We assessed resistance in *E. multicarinata*, *S. occidentalis*, and a third lizard species known to be eaten by black widows (*Uta stansburiana*) through whole-animal performance trials and tissue histology. We obtained baseline sprint speeds, then injected lizards with low (1 mouse LD_{50}) and high (5 mouse LD_{50}) mass-adjusted venom dose treatments. Control animals received injections of saline, and we obtained post-injection sprint speeds from all groups. Following these whole animal trials, we harvested tissue from injection sites for histological examination. We found no statistical decrease in sprint speed between control and treatment groups, though we detected a potential decrease in sprint speed for *U. stansburiana* at the high venom dose. Although the histologic examination is still in progress, we saw evidence for some susceptibility in *U. stansburiana*, while both *E. multicarinata* and *S. occidentalis* appear resistant to the venom of their dangerous spider prey. These data suggest that the predator-prey relationships between some lizards and their spider prey may be more complex than previously imagined, and potentially involve a number of physiological and molecular adaptations that allow lizards to cope with potent arachnid venoms.

51-1 THOMAS, KN*; VECCHIONE, M; JOHNSEN, S; Duke University, NOAA Systematics Lab; *kate.thomas@duke.edu*

Now you see me, now you don't: Cephalopod visual ranges and implications for deep-sea visual ecology

Sunlight in the ocean exponentially decreases with depth, creating a structured and directional optical environment in the midwater habitat. Because of decreasing light availability, it is thought that the distance over which visual interactions among marine animals can occur decreases with depth. This is thought to have major ecological and evolutionary effects; for example, the lower metabolisms of deep-sea cephalopods have been explained by relaxed visual predation with depth. However, species inhabiting the dim twilight zone are also thought to increase relative eye size with depth to cope with low light levels; we previously demonstrated this in cephalopods by comparing measured eye size and body size from species in the Smithsonian collection to species depth distributions and light habitats. Here, we use these data to model maximum theoretical visual ranges for ecologically relevant visual targets such as non-bioluminescent patterning, silhouettes against background light, and bioluminescent patterning. We use a new computational model of contrast attenuation and sighting distances in low-light environments to determine best-case sighting distances for visual targets given eye size, water clarity, downwelling light level, and target size. We discuss how cephalopod eye size affects the potential for resolution with depth, maximum distances over which vision can be used for various tasks, and ultimately the distances over which visual interactions among animals can occur in the deep sea.

84-2 THOMAS, S.G.*; JOHNSON, J.; Western Kentucky University; *samantha.thomas019@topper.wku.edu*

Landscape Genetics of California Tiger Salamanders: Inferences from multiple methods

Landscape genetics is a rapidly growing field of study that compares patterns of gene flow among populations with habitat heterogeneity across a landscape to infer the interaction between dispersal of individuals and their physical environment. Empirical data generated from a landscape genetics study can be implemented for conservation and management purposes, making the field increasing popular. However, concerns have arisen that the field is expanding faster than the analytic framework that supports it. Multiple methods for generating estimates of the association among habitat types and dispersal (i.e., least-cost paths and resistance surfaces) have been proposed, and there is a debate as to which statistical methods are best for examining the genetic structure on a landscape. We use an integrated empirical- and expert-opinion-based strategy to generate a landscape resistance surface for the California Tiger salamander (CTS), *Ambystoma californiense*, which is a species of conservation concern. We utilize several alternative analysis methods (e.g., CCA, MRDM, ResistanceGA, and partial Mantel tests) to look for agreement among methods describing the relationship of landscape features and genetic variation. Our analysis revealed variation among methods for describing genetic structure in this CTS metapopulation, but all methods indicated the presence of genetic structure, to some extent, across the landscape. This empirical data set provides both a perspective on habitat management for the CTS and on the suitability of several novel analysis strategies for landscape genetics.

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Physiological Adaptations for Diving in the Bearded Seal

The bearded seal (*Erignathus barbatus*) is a circumpolar Arctic marine mammal that forages beneath broken, moving pack-ice. Within this dynamic system, seals use sea ice as a platform for rest, but must also dive beneath it to find benthic prey and return to the surface to breathe. For marine mammals, diving capacities depend largely on two factors: how much oxygen an individual carries to depth and how quickly that oxygen is used. A common metric for diving capacity is the aerobic dive limit (ADL), or the time an animal can spend diving before there is an increase in blood lactate. In this study, we utilize data from wild and captive bearded seals to provide the first ADL estimate for this species. Hematological parameters including, hemoglobin (19-31g dL^{-1}) and hematocrit (52-65%) were obtained from free-ranging bearded seals (n = 10) in the Chukchi and Bering Seas, muscle myoglobin content (3.26-4.65g Mb 100g wet $tissue^{-1}$) was determined by analyzing samples obtained from subsistence harvested seals (n = 7) in Alaska, and diving lung volume was estimated based on published values from related species. In addition, seasonal changes in resting metabolic rate (RMR: 3.7-5.5 mL O2 min^{-1} kg^{-1}) were examined in a juvenile male bearded seal trained to participate in metabolic data collection sessions. Using these source data we calculated a range of possible ADL values by dividing total body oxygen stores by different multiples of RMR (providing a range of potential diving metabolic rates). Depending on the assumed seal mass and metabolic rate, we estimate the ADL of an adult bearded seal to be between 4 and 16 minutes; this estimate will be refined as additional source data become available and used to improve predictions regarding the sensitivity of this species to changing conditions.

P1-177 THOMPSON, CM*; POPESCU, VD; Ohio University; *ct824310@ohio.edu*

Climate Change Implications from an Anuran Annual Cycle Perspective

Environmental variation during development can have profound, variable effects on an organism's phenotype, fitness, and physiological attributes. With increasing environmental temperatures and higher frequency of extreme events, ectotherms across the globe are expected to experience thermal ranges and extreme heat events beyond their physiological capacity. Anurans have a dual life cycle, raising the question of whether detrimental environmental conditions experienced in the aquatic (larval) stage are carried over in the terrestrial stage, and whether the negative impacts on growth and survival in the larval stage are exacerbated by changes in temperature and moisture availability in the terrestrial realm. Few studies have considered carryover effects into the metamorph life stage, and fewer have assessed carryover effects throughout an entire annual cycle. This study is designed to evaluate the potential effects of pool permanency on two model amphibians, wood frogs (Lithobates sylvaticus), and American toads (Anaxyrus americanus). My specific objectives are: (1) Evaluate the impacts of pond drying periods on larval development and survival and locomotor performance (endurance) of metamorphs; (2) Evaluate carryover effects of variable pond drying conditions into the terrestrial stage on juvenile growth and survival; (3) Evaluate aquatic and early terrestrial carryover effects on post-overwintering survival and fitness. From initial findings, we have discovered significant variation in size at metamorphosis for wood frogs, but not for american toads and we are now monitoring the growth and survival of individuals in terrestrial enclosures. The biological and physiological insights from this work will help predict amphibian vulnerabilities to climate change of at-risk climate threatened species and inform future conservation strategies.

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Effect of Water Restriction on Baseline CORT and Thermoregulation in Desert Iguana (Dipsosaurus dorsalis)

Prolonged water restriction in arid environments is a potential source of physiological stress to xeric-adapted animals, like desert iguanas (*Dipsosaurus dorsalis*). Such animals may maintain allostasis by adjusting behavior, physiology, and/or morphology to reduce unnecessary water loss and minimize adverse physiological effects of the stressor(s). However, animals must perceive events as a stressor and transduce the information into neural and hormonal responses to facilitate necessary changes. Corticosterone (CORT) is a stress hormone that helps to mobilize energy stores and suspend unnecessary activities. We predicted that populations of *D. dorsalis* that were under water restriction would have higher baseline CORT levels than populations with access to supplemented water through urban irrigation. We measured hematocrit (an indication of dehydration), and baseline CORT levels of two urban populations of *D. dorsalis*, one with and without ("natural") access to irrigated landscaping, in Rancho Mirage, CA in August during the driest part of their active season. Although hematocrit levels from the "natural" site were significantly higher than those from the irrigated site, there were no significant differences in baseline CORT between populations, and no evidence of a significant interaction between site and hematocrit on baseline CORT concentrations. Further analysis of *D. dorsalis* behavior and stress levels upon acute stress are needed to evaluate the entirety of their physiological stress responses to water restriction.

S2-8 THOMPSON, Joseph T; TAYLOR-BURT, Kari R*; KIER, William M; Franklin & Marshall College, Harvard University, University of North Carolina at Chapel Hill; *joseph.thompson@fandm.edu*

Structure and shape affect obliquely striated muscle function in soft-bodied invertebrates

Hollow, cylindrical body plans and obliquely striated muscles are characteristic of soft-bodied invertebrates, and both affect the biomechanics of locomotion and movement in these diverse animals. We highlight two different aspects of functional heterogeneity in obliquely striated muscles, one driven by animal shape and size, and the other driven by the intrinsic mechanical properties of the fibers. First, we show how a hollow, cylindrical shape in cephalopod molluscs causes significant non-uniformities in muscle strain across the body wall, and describe the implications for the length-force relationship of the obliquely striated muscles that power movements in these animals. Moreover, we show how these non-uniformities increase in magnitude as body wall proportions change during growth and development. Second, it has been assumed for decades that oblique striation permits relatively high force output over an extraordinary range of muscle lengths. Recent work in molluscs and annelids, however, has revealed remarkable diversity in the contractile properties of obliquely striated fibers, thus calling this assumption into question. We describe how the length-force relationship (LFR) of cephalopod obliquely striated body wall muscles varies with position to accommodate non-uniformities in strain, and show how the LFR differs from that assumed for obliquely striated fibers. We also present data on diversity in the LFR of cephalopod and annelid obliquely striated muscles, and show that length-dependent activation in some of these fibers is completely different than that described for the skeletal fibers of vertebrates.

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Testing species hypothesis in Speyeria butterflies

Effective conservation and management decisions require robust species hypotheses. The increasing use of next generation sequencing and reduced genome representation methods helps provide a strong scientific foundation for these decisions for even relatively unstudied non-model organisms. Here we take this approach and use restriction associated DNA sequences (RADseq) to evaluate species delimitation in the butterfly genus *Speyeria*. *Speyeria* butterflies are a group of conservation interest across North America comprised of several putative taxa with designations ranging from species of concern to federally endangered. Recent phylogenetic analyses have not confirmed all species to be monophyletic, and inter- and intraspecific relationships require further study. Given that this is a recent and rapid radiation, genome wide data hold promise for elucidating species hypotheses and phylogenetic patterns, as well as paving the way for analyses below the species level. We analyze multiple exemplars from each *Speyeria* species and generate species trees from randomly drawn loci from which we compute a consensus tree to evaluate species lineages and interspecific and intraspecific relationships.

85-8 THOMS, G; LI, C*; Johns Hopkins University;
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Body vibrations induced by legged locomotion help traverse complex 3-D obstacles

Legged locomotion offers natural advantages in complex terrains. When insects and legged robots encounter complex 3-D terrains such as grass-like beams, a rounded body shape helps them roll to traverse narrow slits between beams. In this process, intermittent leg-ground contact induces the animal/robot body to vibrate. Here, we tested the hypothesis that body vibrations induced by legged locomotion facilitate obstacle traversal using an automated robophysical system. To mimic a cockroach/robot body pushing against two adjacent grass blades, we used a linear actuator to move an ellipsoidal body into two adjacent beams with variable spacing. To mimic body vibrations induced by legged locomotion and systematically control and modify the direction and magnitude, we used actuators to generate translational and rotational oscillations on the body. A gyroscope mechanism allowed the body to freely rotate in response to interaction with the beams, and an IMU and cameras recorded the motion of the body and beams. We discovered that both translational and rotational body vibrations facilitated body rolling, increasing traversal probability and reducing traversal time (by 50-80%) as compared to the body without vibration ($P < 0.0001$, ANOVA). Traversal probability increased with and traversal time decreased with beam spacing, suggesting that a more cluttered grassy terrain is more difficult to traverse for a legged animal or robot. Finally, we developed a locomotion energy landscape model to reveal that the kinetic energy from body vibrations better allows the interaction system to explore its state space and find the pathway of rolling traversal, which overcomes the lowest potential energy barrier. Our study supports the plausibility of locomotion energy landscapes for understanding how locomotor transitions emerge in complex 3-D terrains.

39-6 THONIS, AE*; LISTER, BC; Rensselaer Polytechnic Institute, Rensselaer Polytechnic Institute ; *thonia@rpi.edu*

Predicting Climate-Induced Distributional Shifts for Puerto Rican Anoles

With over 400 known species, the lizard genus *Anolis* is the most speciose group of vertebrates in the world. They are also widely distributed, occurring throughout Central and South America, the West Indies, and the southeastern United States. On Caribbean islands, anoles can reach extraordinary densities and are often the dominant members of insular food webs. Although anoles have emerged as model species in studies of ecology and evolution, there has been relatively little research on the effects of climate change on their distributions. Over the past 40 years, Puerto Rico has experienced steady increases in ambient temperature with mean maximum temperatures rising by as much as 2°C. Using distribution data from the Puerto Rico Gap Analysis, WorldClim bioclimatic variables, and MaxEnt niche modeling software, we projected potential changes in the distribution of ten species of Puerto Rican anole for 2050 and 2070. Our models used the HadGEM2 AO Global Climate Model paired with the IPCC's Representative Concentration Pathways (RCPs). RCP8.5 was chosen as it represents a scenario in which greenhouse gas emissions continue to enter the atmosphere after 2100. Model outputs show that under HadGEM2 AO RCP8.5 for 2050, *Anolis krugi*, *A. evermanni*, and *A. gundlachi* are the most negatively impacted species, while for 2070 the most negatively impacted species are *A. gundlachi*, *A. evermanni*, and *A. cristatellus*. The model also predicts reductions in most suitable habitat area across all ten *Anolis* species, ranging from -29.4% in 2050 to -39.6% in 2070. Our study provides insights into the potential impact of continued climate change on Puerto Rican anoles, and likely on other *Anolis* species inhabiting islands in the West Indies, as well as important implications for future conservation efforts.

102-6 TIATRAGUL, S*; PAVLIK, NG; HALL, JM; WARNER, DA; Auburn University, University of New Mexico;
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Nest-site selection in urban dwelling anoles could help embryos beat the heat.

Urbanization dramatically alters the local ecosystem, which impacts resident species. Due to the introduction of impervious surfaces and artificial watering, urban areas have altered thermal and hydric environments. Reptile eggs are directly affected by these altered environments. However, maternal choice of nest microhabitat may be important in buffering the embryos from lethal conditions. In this study, we characterized and compared nest sites of a non-native lizard (*Ctenonotus cristatellus*) in an urban site and a nearby forest site of Miami, Florida. To locate where lizards are nesting, we systematically searched $1m^2$ plots around areas with relatively high abundance of *C. cristatellus* in both the urban and forest sites. We found 112 eggs in total, with 13 plots with nests in the urban site and 31 plots with nests at the forested site (out of 50 plots searched per site). We characterized each plot by recording the thermal and moisture regimes throughout the breeding season, and collected data on other relevant environmental features (e.g., shade cover, distance to trees, distance to roads, etc.). We then compared the conditions of plots with nests to those without nests. Our results suggest that females choose nest sites non-randomly in the urban site as opposed to randomly in the forested site. Additionally, females in the urban site have greater tendency for nest clumping than those in the forest site. Our study provides a rare evaluation of anole nest sites and is the first to quantify environmental characteristics of nests in urban areas. Future studies of offspring survival under these natural conditions will provide evidence for how maternal effects may aid in adaptation and acclimation of non-native species to novel habitats.

S3-7 TIERNEY, SM*; LANGILLE, B; HUMPHREYS, WF; AUSTIN, AD; COOPER, SJB; Hawkesbury Institute for the Environment, Western Sydney University, University of Adelaide, Western Australian Museum, South Australian Museum;
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Massive parallel regression: genetic mechanisms for eye loss amongst subterranean diving beetles

Two tribes of subterranean diving beetles have independently colonised ground water systems of the Australian desert, a habitat transition that was presumably driven by the contraction of surface water bodies during Miocene aridification of the Australian continent. These ‘stygofauna' are now trapped within discrete calcrete aquifer pockets that have formed in paleodrainage valleys, resulting in one of the world's most diverse radiations of subterranean dytiscid beetles. Species exhibit partial or fully regressed visual systems and are essentially blind. This unique study system enables regressive evolutionary processes to be studied in parallel at an unheralded comparative scale - approximately 100 species are now known from two related tribes (Bidessini and Hydroporini). Here we detail the exploration of insect vision genes for signatures of adaptive and neutral evolutionary mechanisms related to eye regression, largely within photoreceptor and eye pigment genes. The transcriptomes of five representative dytiscid beetle species (two surface and three subterranean) were used to design a customized set of RNA baits for hybrid-capture of vision genes and next generation sequencing using Illumina platforms. This methodological design permits the assessment of modifications in the genomic sequence of beetle vision genes at a much broader scale (cf. Sanger sequencing), enabling a higher number of both target species and genes to be simultaneously assessed relative to research time-investments. From a comparative phylogenetic perspective, the potential insights for an improved understanding of the genetic mechanisms underlying regressive evolution generally are thoroughly enticing.

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Muscle Deformations Caused by Myofascial Loads

Many studies have shown that connective tissue linkages are able to transmit force between synergistic muscles. Recently, knee joint movement have been found to cause deformations of muscles that only span the ankle joint (e.g. soleus, SO). Such deformations, involving changes in the distributions of sarcomere length within and between muscles, may affect the mechanical function of these muscles. Although muscle deformations may be caused by myofascial loads (i.e. forces exerted on the muscle belly via intermuscular connective tissues), they do not provide a direct measure of the force transmitted intermuscularly. While we have previously found some force transmission between plantar flexor muscles using invasive experiments on rats and cats, no effects were found on joint level mechanical function. However, in those studies no assessment of muscle deformations was performed. To bridge the gap between the observations from non-invasive kinematic and invasive mechanical measures, we assessed *in situ* effects of knee joint angle (from 70° to 130°) on SO muscle belly length, using sonomicrometry crystals, within an intact ankle plantar flexors compartment of anesthetized Wistar rats (n=3). For each knee angle, passive and active lengths were measured before and during maximal excitation of all plantar flexor muscles, respectively. Varying knee joint angle resulted in limited changes in SO muscle belly length, both during passive (mean: 2.4%) and active (mean: 1.6%) conditions. This indicates that during normal movements in rats myofascial connections between SO and synergistic muscles cause only small deformations of SO muscle belly. This is agreement with the previously reported limited effects of myofascial force transmission on the 3D ankle joint moment of SO.

135-5 TIJS, C*; KONOW, N; BIEWENER, AA; Concord Field Station, Harvard University, Concord Field Station, Harvard University; Dept. Biol. Sci. U. Mass. Lowell; *chris_tijs@fas.harvard.edu*

Cyclical Work done by a Compartmentalized Muscle

Most physiological analyses and musculoskeletal models assume all fascicles of a muscle to have equal biomechanical properties. The pennate rat medial gastrocnemius (MG) is a compartmentalized muscle with proximal fascicles that are shorter and more obtusely angled than the distal fascicles, which draws this assumption into question. Using sonomicrometry in combination with *in situ* ergometry, we evaluate how stimulation magnitude and phase influence the net work done by three MG units: the whole muscle as well as the proximal and distal compartments. Cyclic length changes at 3.5 Hz were imposed, with each cycle starting with a 3 mm stretch, followed by 6 mm shortening and 3 mm re-lengthening. Recruitment level (maximal, submaximal) and stimulation phase (-9%, 0%, +4.5% relative to initial stretch) were varied with excitation for 35% of the cycle. Mass specific net work was calculated for each unit based on their velocity and estimates of compartment mass. At supramaximal activation, increasing stimulation phase affected whole muscle work (-8.9 J/kg to +5.6 J/kg) and distal fascicle work (-7.5 J/kg to +6.3 J/kg) to a similar extent, while work done by proximal fascicles changed from -20.2 J/kg to +0.7 J/kg. Submaximal activation resulted in negative work for all stimulation phases and less variable work output across stimulation phases by whole muscle (-6.5 J/kg to -1.8 J/kg), proximal fascicles (-6.0 J/kg to -1.3 J/kg) and distal fascicles (-7.7 J/kg to -3.5 J/kg). These results suggest that effects of stimulation phase on work output depend on muscle activation levels. They also highlight differences in work output between compartments within a muscle, which may be relevant for musculoskeletal models when estimating the mechanical output of compartmentalized muscles. Funded by NIH AR055648 to A.B.

12-4 TINGLE, J.L.*; HIGHAM, T.E.; Univ. of California, Riverside; *jessica.tingle@email.ucr.edu*

Effects of body size and morphology on sidewinding kinematics in the rattlesnake Crotalus cerastes

Body size affects morphology, physiology, and even behavior across the tree of life, including locomotion ranging from invertebrate peristaltic crawling to tetrapod running. Previous studies on scaling of terrestrial locomotion have shown that kinematics scale inter- and intraspecifically for walking, running, and jumping. However, many animals move terrestrially without limbs, and they face different locomotor challenges than do limbed animals. Because limbless terrestrial animals range across orders of magnitude in size, and because they move so differently than limbed animals do, studies of scaling of limbless locomotion would deepen our understanding of the diversity of effective movement on land. We examined the scaling of sidewinding locomotion in the rattlesnake *Crotalus cerastes* by collecting various morphological measurements and high speed video of 74 sidewinder rattlesnakes ranging in size from 8 g to 272 g. Several morphological characters scaled allometrically with body mass, including tail length, elongation ratio, head length, head width, head length : width ratio, and head width : neck width ratio. In addition to the changes in body shape, we expected changes in the kinematics of sidewinding motion, perhaps mediated in part by changes in body shape. Preliminary results suggest that certain kinematic variables, such as the height to which the snakes lift their bodies as they move forward, scale allometrically. We also analyzed instantaneous velocity and acceleration of points along the body, as well as local curvatures. Moreover, individual variation in morphological characters will allow us to examine whether aspects of morphology such as relative tail length, slenderness, or number of body vertebrae affect sidewinding kinematics.

83-6 TIVEY, TR*; ADPRESSA, DA; MANDELARE, PE; PARKINSON, JE; LOESGEN, S; WEIS, VM; Oregon State University; *tiveyt@oregonstate.edu*

Novel glycan biosynthesis manipulation of Symbiodinium impacts onset of cnidarian-dinoflagellate symbiosis

Glycan-lectin interactions are a fundamental mechanism of interpartner communication involved in innate immunity and host-microbe interactions. During onset of cnidarian-dinoflagellate symbiosis, cnidarian gastrodermal cells bind sugar residues on their algal partners. These algal glycans are important for recognition and may in part mediate host-symbiont specificity. We aimed to manipulate the *Symbiodinium minutum* glycome to determine the effect of specific glycan enrichment and simplification on symbiont colonization success. *S. minutum* cultures were treated with two different mannosidase inhibitors, kifunensine and swainsonine, which directly inhibit endogenous glycan biosynthesis pathways in the ER and Golgi, respectively. To test for efficacy, cultures were incubated with lectin-conjugated fluorophores that specifically labeled high-mannose glycans. Flow cytometric analysis revealed that both kifunensine- and swainsonine-treated cultures showed significant enrichment for high-mannose compared to untreated cultures. After confirming high-mannose enrichment, we then compared colonization success of each culture in the symbiotic sea anemone, *Aiptasia pallida*. Colonized hosts were imaged three days after inoculation. Kifunensine-treated cells had significantly lower colonization compared to untreated cells, measured via symbiont density. A similar decrease in colonization was found with *S. minutum* cells modified via glycosidase surface cleavage. Together, these results suggest that simplified glycans decrease the colonization success of *Symbiodinium*, and highlight the importance of complex glycans in symbiosis recognition.

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Examining the Musculoskeletal Ontogeny of Cranial Kinesis in Birds Along the Precocial-altricial Spectrum

Avian hatchlings on the precocial-altricial spectrum are characterized by their external appearance, rate of overall body development, and by their sophistication of feeding behaviors. Among these, potential for cranial kinesis (e.g., coordinated motion of intracranial joints) is presumed to vary predictably, with precocial birds consistently demonstrating mature cranial musculoskeletal anatomy as compared to their altricial counterparts, regardless of absolute body size. To formally evaluate whether early feeding behaviors are reflected in hatchlings' cranial musculature and subsequent growth, we used standard micro-computed tomography (μCT), diffusible iodine-based contrast-enhanced CT imaging, and digital dissection to study size and scaling patterns of the avian jaw to compared the delicate soft- and hard-tissue functional morphology of jaw closure and cranial kinesis in hatchling and adult birds of the precocial domesticated chickens (*Gallus domesticus*) and the altricial estrildid finches (*Lagonosticta senegala*). By documenting how early-life feeding strategies correlate to the ontogeny of avian cranial characteristics of hatchling through adulthood along this spectrum, we aim to clarify differences in developmental variation and potential flexibility in the functional anatomy of the kinetic mechanism as a framework for examining the evolutionary origins of neognathine feeding diversity that has contributed to the extraordinary success of modern avifauna.

134-4 TOBALSKE, BW*; LANE, SJ; WOODS, HA; SHISHIDO, CM; MORAN, AL; Univ. Montana, Univ. Hawaiʻi, Mānoa; *bret.tobalske@mso.umt.edu*

Ecological Limits and Locomotor Advantages Associated with Gigantism in Polar Sea Spiders

Sea spiders vary over five orders of magnitude in body size; temperate species are small whereas polar and abyssal species can be huge. They are thus a useful model for identifying ecological factors that drive observed biogeographical distributions of gigantism and for testing the adaptive significance, if any, of being large in polar waters. Our recent research into the bending strength of the legs of sea spiders led us to hypothesize that the distribution of large species is limited by oceanic current. We tested this hypothesis by measuring: drag that large sea spiders would experience in temperate waters using a submerged, 3D printed model attached to a force transducer, clinging strength of live sea spiders in their natural habitats in response to induced current, and the effects of flow velocity on locomotion in a water flume. We tested for potential selective advantages of large body size by measuring walking speed during escape and sinking rate in water. Consistent with our current-limitation hypothesis, flow velocities during a large-flux tide cycle in temperate sea-spider habitat were 3-5x greater than velocities that significantly reduced locomotion in large sea spiders, and peak drag upon our 3D model was >150x body weight. This peak drag was 5x the force required to break the legs of sea spiders. Small sea spiders live within boundary layers and thus appear to be sheltered from high velocity and drag. Induced current caused large sea spiders to detach from their substrates, but their clinging strength depended upon surprise and substrate type. Escape speed and sinking rate increased with body size. Gigantism may thus allow sea spiders to exploit ephemeral, patchy food resources and to control their body position after disturbance such that they select and remain in desirable habitat. NSF PLR- 1341485.

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Within and Among Year Variation in Reproductive Output from Two Populations of the Diamond-backed Terrapin, Malaclemys terrapin

Optimal egg size theory predicts that selection should favor a single egg size that simultaneously maximizes female and offspring fitness. Deviations from an optimal egg size exist where extrinsic factors such as temporal variation in temperature, humidity, and incubation substrate have been shown to influence reproductive output in many taxa. We investigated variation in reproductive output between two populations of the Diamond-backed Terrapin, *Malaclemys terrapin*, in Maryland over multiple years. Data was acquired from excavated nests and gravid female x-rays in the Patuxent River and excavated nests from Poplar Island. In both populations females lay multiple clutches within a nesting season, and egg size within clutches varies little during the first half of the nesting season. However, within clutch egg size variation increases in subsequent clutches suggesting that resource availability and environmental stochasticity during the inter-clutch interval results in a "sloppy" allocation strategy where females switch from "capital" to "income" breeding between first and subsequent clutches respectively. Female size and pelvic aperture width correlated weakly with egg width in the Patuxent River. Poplar Island egg and hatchling metric comparisons indicate there is a strong relationship between egg and hatchling size, and within clutch variation in egg size was mirrored in variation in hatchling size. Our findings suggest that egg size is not constrained by female morphology and appears to be optimized for female over offspring fitness by maximizing the number of offspring as resources allow. We also suggest that variation in egg size is influenced by either environmental variation or resource availability during inter-clutch periods.

P1-222 TOMAN, T*; BROWN, S; LOWERY, MS; Univ. San Diego; *slowery@sandiego.edu*

Enzyme Correlates of Aerobic and Anaerobic Metabolism in Hatchery Reared versus Wild Caught California Yellowtail Seriola dorsalis

California Yellowtail, *Seriola dorsalis*, are highly migratory yet few studies have looked at the impacts of hatchery rearing on muscle characteristics and swim capacity of these fish. Glycolytic (lactate dehydrogenase, LDH, and pyruvate kinase, PK) and oxidative (citrate synthase, CS) enzyme activities in juvenile wild caught and age matched hatchery-spawned yellowtail were compared at capture and after an eight-month period in standard aquaculture tanks. Wild yellowtail had a lower standard metabolic rate and higher aerobic scope at capture, but no difference in muscle CS activity. Hatchery-spawned fish had higher PK and LDH activities than wild caught fish upon capture, but most differences in glycolytic activities seen initially dissipated in captivity. Only PK activity remained higher in the white muscle of hatchery-spawned fish after 8 months. Following the hatchery rearing period, wild caught yellowtail had 15% lower CS activity in both white and red muscle than hatchery-spawned fish, indicating a relatively lower maximum aerobic capacity in the muscle. However, the reduction in CS was fairly modest considering an assumed substantial loss of daily activity in the hatchery setting compared to the wild. Overall, there was little difference in these biochemical indicators of muscle metabolism in hatchery reared versus wild caught yellowtail.

120-6 TOMANEK, L*; VASQUEZ, MC; California Polytechnic State University; *ltomanek@calpoly.edu*
Sirtuins: Regulators of the Response to Heat and Hypoxia Stress in Mytilus Mussels
Sirtuins are NAD-dependent deacylases, which change the activity of proteins by removing acyl groups that are linked to energy metabolism, e.g., acetyl-CoA. While their general effect on the proteome is well characterized, their specific role during the response to heat and hypoxia stress is not, neither is the interspecific variation that underlies differences in stress tolerance. We investigated the proteomic changes in gill tissue of *Mytilus trossulus*, which is native to the Pacific coast of North America, and *M. galloprovincialis*, a more heat-tolerant invader from the Mediterranean, which replaced the native in the southern part of its range. Using sirtuin inhibitors, we identified differences in how sirtuins affect molecular chaperones, oxidative stress proteins, metabolic enzymes, cytoskeletal and signaling proteins in the two congeners. Interactions between sirtuin inhibition and changes in the abundance of proteins of β-oxidation and oxidative stress in *M. trossulus*, suggest a greater role of sirtuins in shifting metabolism to reduce the production of reactive oxygen species near thermal limits. Furthermore, sirtuin inhibition affected RNA-binding proteins initiating and inhibiting translation in *M. galloprovincialis* and in *M. trossulus*, respectively. While both species responded to hypoxia with increases in several molecular chaperones and proteins involved in protein degradation, *M. trossulus* showed a unique increase in small heat-shock proteins. *M. galloprovincialis* showed a tiered response to oxidative stress under hypoxia, while the response of *M. trossulus* was muted. It is likely that these interspecific differences in the effects of sirtuins contribute to setting stress tolerance limits (funded by NSF IOS-0717087 and PRFB DBI-1401357).

P2-168 TOMKINSON, IK*; RIESER, JM; SCHIEBEL, PE; PAZOUKI, A; GODDARD, Z; PULLIAM, J; NEGRUT, D; GOLDMAN, DI; Georgia Tech, California State University, Los Angeles, University of Wisconsin, Madison; *itomkinson3@gatech.edu*
Improving performance of a snake-like robot in heterogeneous terrain by managing effects of head collisions
Limbless robots have the potential to assist with many applications, however their performance in heterogeneous environments does not match that of living systems. In particular, collisions with obstacles may lead to unwanted reorientations, impacting the ability of the robot to reach a goal. We hypothesize that sensing robot-obstacle contact forces and durations from collisions could be used to decrease the duration of the collision or reorient itself advantageously. To learn how important collisions - those with the head -- affect locomotion, and how these interactions could be used to assist the snake, we studied a simple robophysical snake moving through vertical posts. The robot locomotes on hard ground by commanding the joint angle positions of 12 servo motors to vary sinusoidally with time and position along the body, and uses passive wheels attached to each segment to provide a frictional anisotropy. In an open-loop robot without sensing, the robot is "diffracted" by collisions. This rotation is dominated by head-obstacle collisions with larger rotations resulting from longer contact durations. We hypothesize that integrating sensing on the head of the robot will enable the robot to reduce collisional diffraction effects. Simulations show that there is a positive correlation between snake amplitude and scattering angle, so we expect that reducing the snake amplitude at the time of contact will reduce scattering behavior. We added capacitive sensors to the robot head and tested control schemes which temporarily and locally modify the shape of the snake to reduce the duration of the contact with the peg.

P2-147 TORJMAN, BZ*; IYENGAR, EV; Muhlenberg College; *bt250902@muhlenberg.edu*
Ecological Ramifications of Snail Shell Use by Hermit Crabs
The intertidal zone of the United States Pacific Northwest carries many threats for hermit crabs, including predation, desiccation and temperature stresses. We conducted transect surveys examining the shell use of two species of hermit crabs (*Pagurus granosimanus* and *Pagurus beringanus*) in different microhabitats (exposed versus tide pools) at five sites on San Juan Island, Washington state. We found few empty shells available to hermit crabs, implying intense competition for refuges among individual crabs. Further, the two species inhabited different microhabitats. We compared the relative frequency of live gastropod species and the shells used by the hermit crabs, and examined whether shell weight varied consistently with hermit crab body mass across hermit crab species, shell species and sites. Our lab choice experiments revealed that hermit crabs do not prefer the gastropod shells they are most commonly found to inhabit in the field, and this choice was often not driven by shell weight alone. We demonstrated that while the preferred shells, which had thicker walls, could elevate protection against small predatory crabs, large predatory crabs could consume any of the shell choices.

P3-62 TORRES, TD*; RUIZ, R; WATSON, CM; SHIPLEY, M; Midwestern State University, Midwestern State Univerisity; *tdtorres95@yahoo.com*
Assimilation of fatty acids present in milkweed species (Asclepias) by specialist insect herbivores
Milkweed of the genus *Asclepias* are a group of plants that produce toxins to deter defoliation by herbivores. Despite this defense mechanism, there are many invertebrates that feed upon this group exclusively. Among those are two true bugs, a beetle, and the larvae of the Monarch butterfly. We are interested in the variation of macromolecules among *Asclepias* species and if these differences are reflected in the tissue of the herbivores that feed upon them. *Asclepias viridis* and *A. asperula* leaves were used to construct a lipid profile to analyze the assimilation of fatty acids by the Large Milkweed Bug (*Oncopeltus fasciatus*). We also profiled the tropical species, *A. currisavica*, for a more robust comparison of lipid profiles among species. Lipids were extracted from leaf samples and the tissue of the bug using a mixture of chloroform/methanol/water in a 4:2:1 ratio, converted to fatty acid methyl esters, and analyzed by Gas Chromatography-Mass Spectrometry. The fatty acid within milkweed that were found in highest abundance was palmitic acid (16:0) followed by stearic acid (18:0). These same fatty acids were found in the insect tissue, yet in different ratios. Additionally, smaller amounts of odd chain fatty acids, uncommonly found in biological systems, were present within the milkweed leaves. These data provide avenues for further study. These methods will be extended to the imperiled Monarch butterfly to better understand transfer of energetically important molecules from plant to herbivore.

P2-99 TORRES JARIN , J/M*; GOSLINER , T/M; San Diego State University , California Academy of Sciences ; *janster95@yahoo.com*

Dancing with Dorids: Phylogenetic Systematics of Discodorid Nudibranchs in the Genus Rostanga

The discodorid nudibranchs are a family within Doridina, characterized by a gill plume surrounding the anus and a pair of finger-like oral tentacles. Members of the discodorid genus, *Rostanga* (Bergh 1879), can typically be identified by their red-orange to orange coloration, which they obtain from their diet of sponges. Sponge-eating species of *Rostanga* possess caryophyllidia and can be found in most of the world's oceans. Morphology and anatomy alone are often insufficient for determining evolutionary relationships within *Rostanga*. This project investigated the relationships of newly collected taxa in order to determine if there is undocumented diversity within *Rostanga* based on observed variation in coloration and the presence of caryophyllidia. In this study, we present a phylogenetic analysis of *Rostanga* using mitochondrial COI and 16S genes along with the nuclear H3 gene. Relationships were tested using known species of *Rostanga* and newly collected specimens using the outgroup *Discodoris cebuensis*. Additionally, we used scanning electron microscopy (SEM) to view characteristics of the radula such as shape, size, and number of teeth, and dissected specimens to determine orientation of their reproductive systems. Preliminary results indicate that some *Rostanga* possess morphological characters that are atypical of the genus and may not be considered a "true" *Rostanga*. There is some support for a grouping of true *Rostanga* that possess elongate outer teeth with divided tips. Increased taxon sampling, additional molecular studies, and a reevaluation of morphological characters used for description will allow for more accurate delimitation of evolutionary relationships within this group.

S7-6 TOWNS, BJ; GILL, KS*; Center for Design Innovation, UNCSA, Tributary Land Design; *betsy.towns@gmail.com*

Play to Learn, Learn to Play: the role of design in creating places for learning.

This session is for those who have ever wondered about how to influence students' preparation for STEM careers. It is for professors and researchers wondering how to shape others' ability to ask questions and investigate a problem, and see the consequences of structure and function in the natural world. Though examples mount to demonstrate that hands-on, inquiry-driven learning effectively cultivates the critical and creative thinking skills needed for discovery and innovation, mainstream schools have to balance this type of instruction with fact delivery and test prep. Yet alternative learning environments such as museums, zoos, and farms routinely offer both the capacity to communicate critical knowledge and platforms for prototyping and assessing inquiry-driven methods for teaching and learning. We show how we rely on design practice to create place-specific experiences to allow visitors to learn for themselves: when they create a nature trail, and conduct creek research, and climb through a landscape that makes them feel the size of ants, they learn their impact on the landscape and how to empathize with creatures that may look different from them. How do we know when a creation works? How do we know when a design is the right design? During the session we speak to our design process, fruitful and frustrating collaborations, and protocols for improving our process and practice.

8-5 TOWNSEND, JP*; SWEENEY, AM; University of Pennsylvania; *townj@mail.med.upenn.edu*

The Presence of DOPA Derivatives in Ctenophore Colloblast Adhesive Suggests a Structural Role for Catechols at the Base of the Animal Tree of Life

Ctenophores, or comb jellies, are likely the earliest-diverging extant animal lineage. Given the group's apparent physiological complexity, this recent finding was unexpected and remains difficult to contextualize. Part of this difficulty arises from the various poorly understood aspects of ctenophore biology. For example, an enduring source of mystery within the phylum is the colloblast, a cell type unique to ctenophores. Colloblasts are destructible cells found in these animals' tentacles that release a fast-acting adhesive on contact with prey, ensnaring it. To date, little is known about this adhesive or its biochemistry. In this study, we present new evidence that the colloblast adhesive of the ctenophore *Pleurobrachia bachei* contains proteins that incorporate derivatives of the amino acid DOPA, suggesting a parallel with the adhesive foot proteins of mussels. We also find immunohistochemical evidence suggesting the presence of similar DOPA derivatives in the *Pleurobrachia* subepithelial nerve net. This latter finding is notable given ctenophores' reported lack of the enzymatic machinery to produce or utilize catecholamine neurotransmitters such as dopamine. Our data point to a structural role for DOPA-like compounds in ctenophores, which in turn suggests that this noncanonical role for these molecules may be a deeply-rooted animal trait that arose independently of catecholamine neurotransimission.

P3-249 TOWNSEND, JP*; TASSIA, MG; DAMIAN-SERRANO, A; WHELAN, NV; HALANYCH, KM; SWEENEY, AM; University of Pennsylvania, Auburn University, Yale University, U.S. Fish and Wildlife Service; *townj@mail.med.upenn.edu*

A Colorful, Deep Sea Ctenophore Species From the Northwest Atlantic Ocean

We report an undescribed species and genus of tentaculate ctenophore, nicknamed "Delmarva red," caught by Tucker trawl off the coast of Delaware at a depth of approximately 600 m. Individuals presumed to be adult representatives of the species are approximately 8 cm in length, with bright red bodies, a pair of orange tentacles, purple comb rows, and a prominent black gut whose pigmentation likely aids in the concealment of consumed bioluminescent prey. Phylogenomic analyses suggest that "Delmarva red" is sister to *Euplokamis dunlapae*. Together these two species are recovered as the sister group to all other extant ctenophores. "Delmarva red" appears superficially similar to the "Tortugas red" ctenophore from the Caribbean that has been referenced in various past studies of the phylum. It is possible that "Tortugas red" and "Delmarva red" are one and the same, and that the species is cosmopolitan in the Atlantic, but further sampling will be necessary to assess this biogeographical point.

28-1 TOXOPEUS, J*; DES MARTEAUX, LE; KOSTAL, V; SINCLAIR, BJ; Western University, Czech Academy of Sciences; *jtoxopeu@uwo.ca*

Why Frozen Insects Die: A Tale of Metabolomics, Transcriptomics, and Cryoprotectant Manipulation in Freeze-Tolerant Crickets

Ectotherms overwintering in temperate climates may freeze, causing damage and death. Some insects - such as juveniles of the spring field cricket, *Gryllus veletis* - are freeze tolerant: they survive internal ice formation. However, we have limited understanding of the mechanisms underlying insect freeze tolerance and its limits. A fall-like laboratory acclimation induces freeze tolerance in *G. veletis*, along with substantial changes in its transcriptome and metabolome. Freeze-tolerant crickets accumulate three potentially cryoprotectant molecules (trehalose, proline, and *myo*-inositol) in their hemolymph and fat body tissue, and differentially express several stress tolerance genes. To investigate cryoprotectant function in freeze tolerance, we elevated their concentrations *in vivo* and *ex vivo*. No cryoprotectant - either in isolation or in combination - was sufficient to confer freeze tolerance on freeze-sensitive morphs of *G. veletis* (*in vivo*) or their fat body tissue (*ex vivo*). However, injecting cryoprotectants into freeze-tolerant crickets improved survival at the lower lethal temperature (LLT) and lethal time (Lt). High exogenous cryoprotectant concentrations improved freeze-tolerant *G. veletis* fat body survival at the cellular LLT and Lt when frozen *ex vivo*. No cryoprotectant or combination of cryoprotectants improved both organismal and cellular survival at the LLT and Lt. These results suggest that cryoprotectants differentially contribute to cellular and whole organism survival of freeze-tolerant *G. veletis*, and several mechanisms contribute to preventing mortality in the frozen state.

29-6 TRACY, CR*; GORDON, M; SIMANDLE, E; NOLES, P; SANDMEIER, F; HAGERTY, B; FISHER, R; BECK, M; FORISTER, M; Univ. of Nevada Reno, Paul Smiths University, Colorado St. Univ. Pueblo, York Univ. of Pennsylvania, USGS, San Diego, Calif. St. Univ. Northridge; *dtracy@unr.edu*

Phylogeography of Toads in the Bufo. boreas species complex

Toad populations of the western toad (*Bufo boreas*) species complex are found throughout the western U.S. from Colorado to the Pacific Ocean and from Alaska to western Mexico. The phylogeography of the several species and evolutionary significant units (ESUs) within this complex has been reconstructed from phylogenetic analyses and the paleohydrology of the Great Basin populations to estimate times in which each of the species or ESUs became separated and started on their trajectory towards significant differentiation. The Humboldt/Lahontan ESU located in most of northern Nevada, separated from the Mojave ESU approximately 1.6 million years ago when a pluvial period connected populations through what today is Mono Lake. *Bufo williamsi* in Dixie Valley, Nevada, separated from the Humboldt/Lahontan watershed approximately 650,000 years ago during a postpluvial period created a barrier between Lake Lahontan and Dixie Lake. *Bufo monfontanus* in central Nevada likely separated from populations in Lake Bonneville a dry period in the late Pliocene, and *B. nevadensis* separated from Nevada populations when the wet areas on Railroad Valley, NV became isolated from the White River, which drained into the Colorado River which formerly connected Colorado populations of toads with those in Railroad Valley about 5 to 20 million years ago. The Amargosa toad currently found in Oasis Valley in southern Nevada is clearly an ESU, but its differentiation from other populations in the Mojave Desert is very recent (less than 15,000 years), and all populations in the Mojave Desert should reasonably considered to be *B. nelsoni*. These analyses provide perspective on the natural history of an entire species complex of toads in the U.S.

S9-3 TREBERG, JR; University of Manitoba; *jason.treberg@umanitoba.ca*

Peering Inside the Black Box: Comparing Mitochondrial Electron Leak in Vertebrate Muscle

Mitochondria are central to energy transformation in animals but the cascade of electron transfer from oxidative fuels to the terminal formation of water is not completely efficient: some electrons can prematurely escape. As these electrons ‘leak' from the canonical electron transfer pathways they contribute to the formation of reactive oxygen species (ROS) such as superoxide and H_2O_2. These mitochondrial ROS have been implicated with growth and performance trade-offs, signalling, as well as with aging and senescence related declines in function; although, the latter relationship has become somewhat beleaguered. However, relatively few studies have delved deeply into comparing and explaining differences in mitochondrial electron leak across species. Complicating such comparisons, there are > 10 potential sites of significant electron leak in mitochondria. The many candidate sites of ROS formation, combined with differential reliance on intramitochondrial antioxidant systems, makes it complex to derive straightforward comparisons across or within species. But the magnitude and nature of mitochondrial superoxide/H_2O_2 formation is intrinsically linked to mitochondrial energetics. Therefore this complex system can often be best understood by assessing multiple levels of mitochondrial function. Here the convoluted interrelationships mitochondrial ROS metabolism has with respiration rate, membrane potential, and electron carrier reduction state are examined. In doing so the importance of tissue type, assay condition and the means of normalizing data for comparison across muscle mitochondria from endotherm and ectotherm vertebrates will be considered.

P1-122 TREIBERGS, KA; Harvard University, Cambridge, MA; *ktreibergs@g.harvard.edu*

How Does a Bryozoan Colony Divide Labor Among its Modules?

Bryozoans are a diverse phylum of marine and freshwater colonial invertebrates containing over 5,000 described living species. Bryozoans grow by budding of new colony members (zooids) from a metamorphosed larva, however, these modules often come in different shapes and sizes and are specialized to serve different tasks within the colony. Zooids range in function from feeding to reproduction, structure, defense, and colony attachment. A complex interaction of genotype, environment, and developmental pathway shapes zooid formation, however, the specific mechanisms underlying the establishment of this division of labor remain unknown. I am investigating the development and morphology of lab-cultured *Bugula stolonifera* using RNA-sequencing, differential gene analysis, and confocal imaging. I developed a technique to extract high-quality mRNA from small colony structures (<100 µm avicularia and <50 µm avicularia buds) by pooling together dissected tissue from a single genetic individual, enabling building cDNA libraries for three different zooid types at two different developmental states with three biological replicates per tissue. Sequencing on the Illumina platform yielded 298 million paired-end reads (after quality control) to build the reference transcriptome, which is currently in assembly via the Trinity pipeline. I will pair subsequent differential gene expression analyses with confocal imaging of different zooid types throughout development, to form an understanding of the developmental mechanisms involved in the formation of the zooids of *B. stolonifera* and provide new insights into the evolution of coloniality and polymorphism in bryozoans.

128-4 TREIDEL, LA*; CHUNG, DJ; WILLIAMS, CM; UC Berkeley, University of British Columbia; *lisa.treidel@berkeley.edu*
Mitochondrial performance differs in concordance with life history strategies and energetic demands in the wing-polymorphic cricket, Gryllus firmus
Organisms differ in resource allocation towards life history traits including growth, reproduction, activity, and maintenance, thus defining their life history strategy and metabolic demands. Variable energetic demands are met via differential flux of ingested nutrients through metabolism. Central metabolic pathways converge in the mitochondria, making this organelle the epicenter of life history allocations. We hypothesized that alternative life history allocations are underpinned by differences in mitochondrial function and tested the prediction that mitochondrial plasticity accompanies shifts in life history energy demands. Morphs of the wing-polymorphic cricket *Gryllus firmus* specialize either in dispersal (LW) or reproduction (SW). In early adulthood, LWs maintain functional flight muscle and accumulate lipid stores for flight, while SWs invest in ovary growth to reach an early reproductive maturity. Using high resolution respirometry, we characterized rates of mitochondrial respiratory function (State III, State IV, Cytochrome *c* oxidase capacity (CCO)) when fueled by multiple substrates (pyruvate, malate, glutamate, succinate) of LW and SW female adults across ontogeny (1, 3 or 5 day-old). At day one, mitochondrial respiration was similar in the morphs but diverged gradually, such that by the time LW are prepared to fly and SW have completed ovary synthesis, State III was significantly higher in LW than SW. CCO was correlated with State III suggesting that alterations in mitochondrial densities may underlie observed mitochondrial plasticity. Overall, these results indicate that divergence of mitochondrial respiration may be integral to the expression and constraint of life history strategies.

P1-92 TRICOLA, GM*; SIMONS, MJP; VLECK, CM; HAUSSMANN, MF; Bucknell University, University of Sheffield, Iowa State University, Bucknell University ; *gmt004@bucknell.edu*
Comparative insights into telomere biology
Telomeres are conserved DNA sequences that serve as protective caps for linear DNA. Over time, telomeres degrade due to factors including the end-replication problem and oxidative stress. Once telomeres reach a critical length, they initiate a cell signalling pathway resulting in cellular senescence, a hallmark of aging. While telomeres are well-studied in the context of senescence at a cellular level, the relationship between telomeres and organismal longevity is less understood, as most studies focus on within species rather than across species phenomena. Here, we use cross-sectional telomere data from nineteen species to investigate four recent hypotheses in the telomere biology literature: (i) whether the maximum lifespan of a species is associated with either the mean telomere length of that species, or (ii) the telomere loss rates of that species, (iii) whether short telomeres and fast attrition rates play a causal role in aging, as suggested by the telomeric brink hypothesis, and (iv) whether long telomeres are more subject to damage-induced shortening compared to short telomeres. We found that in birds telomere shortening rates (ii), but not mean telomere length (i) relates to species maximum lifespan. In addition, we find no support for the telomeric brink hypothesis (iii) or that longer telomeres are more subject to shortening compared to short telomeres (iv). Our study highlights that comparative data sets can provide powerful insight into the relationship between telomere biology and organismal longevity.

P3-109 TRIPP, JA*; BASS, AH; Cornell University; *jat334@cornell.edu*
Galanin Neuron Distribution and Activation in a Fish with Alternative Reproductive Tactics
Studies across vertebrate lineages show that galanin (gal) is a neuropeptide that plays an important role in regulating both reproductive and parental behavior. We have found that gal transcript expression varies across reproductive behavioral state in a fish with alternative reproductive tactics, the plainfin midshipman (*Porichthys notatus*). Male midshipman have two morphs that reproduce either through defending nests and courting females (type I males), or cuckolding at the nest of courting males (type I or type II males). Here, we used immunohistochemistry and an antibody specific to midshipman gal to identify cells in the midshipman brain expressing gal peptide and describe the sites of their projections. Gal-immunoreactive (ir) cell bodies occurred in the anterior and posterior parvocellular preoptic area (POA), with dense projections of gal-ir processes into regions strongly implicated in regulating social behavior, including the ventral nucleus of the ventral telencephalon (proposed homology to mammalian septum) and midbrain periaqueductal grey (PAG); and vocalization, including the supracommissural nucleus of the ventral telencephalon (proposed homology to basal amygdala) and PAG. Dense gal-ir processes and putative terminals were also observed in sensory processing sites for vision in the pretectum and tectum; and for audition and/or lateral line in the forebrain, midbrain and hindbrain. Label was generally robust throughout the midbrain tegmentum and hindbrain reticular formation that included the region of premotor neurons of the vocal central pattern generator. Finally, we used double-labelling with pS6, a protein marker of neuron activity, to identify changes in gal-ir neuron activity in the POA during spawning in courting and cuckolding males. Research support from NSF IOS 1656664 and Cornell University.

P1-172 TRUDEL, JM*; CHOI, C; PECHENIK, JA; PIRES, A; Tufts University, Dickinson College; *jaime.trudel@tufts.edu*
Chemical Cues for Metamorphosis in the Marine Snail Crepidula fornicata, and the Effects of Ocean Acidification on Cue Perception
Larval metamorphosis of benthic marine invertebrates is often regulated by chemical cues that indicate the best place to settle, metamorphose, and survive to adulthood. These stimuli determine the distribution of many species and impact the structure of marine communities. With substantial decreases in ocean pH levels expected by 2100, it is important to look into the effects of ocean acidification (OA) on the ability of marine organisms to perceive metamorphic cues. In this study we sought to identify the sizes at which individuals of the marine gastropod *Crepidula fornicata* do or do not release metamorphosis inducing stimuli, and if there are other cues (e.g., biofilms) that induce metamorphosis. We also examined the impact of reduced pH (7.5 versus pH of 8.0) on induction. Competent larvae (4 replicates of 10-12 larvae each) were exposed to potential cues for 3-6 hours to assess the source of metamorphic cues. Sources included *C. fornicata* adults (2-30 mm shell length), the body of the adult snails without shells, shells with the body removed, and shells sterilized to remove biofilms and symbionts. 20 mm excess KCl and Instant Ocean at 30 ppt served as positive and negative controls, respectively. Individuals $\geq$ 7 mm in shell length were most effective at inducing metamorphosis. The body of the snail and biofilms on the shell alone both induced metamorphosis, but less effectively than intact adults; sterilized shells did not induce metamorphosis. Reduced pH had no significant effect on the ability of large adults (28.13 ± 2.8 mm) to stimulate metamorphosis. Our results suggest that multiple chemical cues induce metamorphosis, and that OA will have no significant effect on larval perception of cues for metamorphosis in this species.

P3-46 TSAI, OH*; YAP, KN; WILLIAMS, TD; Simon Fraser University; *otsai@sfu.ca*
Birds and Mammals Differ in the Effect of Dietary Nitrate on Hemoglobin and Hematocrit
Hemoglobin (Hb) and hematocrit (Hct), two major predictors of oxygen carrying capacity, are thought to contribute to variation in individual aerobic performance. Indeed, these blood parameters seem to vary adaptively in response to important life-history events in birds, such as breeding, migration, and winter acclimatization. Most of the current studies investigating individual variation in hematology, aerobic capacity, and life-history are correlational. Thus, there would be considerable value in developing methods for experimental manipulation of Hb and Hct, but existing methods are either expensive or use pharmacological agents with potentially harmful side effects. Recently it was reported that nitrate administration can effectively lower Hb and Hct in mammals (rats). Dietary nitrate is endogenously reduced to nitric oxide (NO) via the nitrate-nitrite-nitric oxide pathway. NO is, in turn, hypothesized to increase mitochondrial efficiency, lowering the oxygen cost of exercise and thus allowing for the down-regulation of blood parameters such as Hb and Hct. We attempted to confirm and validate this finding in birds by conducting three dose-response studies in captive zebra finches (*Taeniopygia guttata*). Preliminary analysis suggests that there is no consistent effect of nitrate on blood parameters in this species (cf. mammal studies). We will report results of further experimental trials and measurements of plasma nitrate concentration in our experimental subjects. Specifically, we will test the prediction that birds dosed with higher concentrations of nitrate will have higher plasma nitrate levels and will show a dose-dependent modulation of Hct and Hb.

P2-227 TSAI, HP*; TURNER, ML; MANAFZADEH, AR; GATESY, SM; Brown University; *henry_tsai@brown.edu*
Significance of hip kinematics for interpreting articular soft tissue function in Alligator mississippiensis
Archosaurs (birds, crocodylians, and their extinct relatives) evolved a wide diversity of hind limb skeletal morphologies, suggesting highly divergent articular soft tissue anatomies. However, the general lack of understanding on the dynamic interaction of archosaur joint soft tissues has hampered further functional and evolutionary inferences. Here we use contrast-enhanced computed tomography to generate 3D surface models of the pelves, femora, and joint soft tissues of the American alligator, an extant archosaur. The hip joints were then animated using marker-based XROMM to visualize soft tissue articulation and hip kinematics during forward terrestrial locomotion. The anatomical femoral head of the alligator travels beyond the cranial extent of the bony acetabulum and does not act as a central pivot as has been suggested for some extinct archosaurs. Moreover, the apex of the hyaline cartilage core interpenetrates with the ventral surface of the acetabular labrum during load-bearing phases of the high-walk, suggesting deformation of the labrum in response to compressive loads. Finally, the fibrocartilaginous surfaces of the alligator's antitrochanter and femoral neck remain engaged during hip flexion and extension, similar to the articulation between homologous structures in birds. Our results illustrate the utility of XROMM for studying joint kinematics in light of articular soft tissue interactions. These results also allow us to propose functional hypotheses for crocodylian hip joint soft tissues, which expand our knowledge in vertebrate connective tissue biology, loading mechanics, and the role of joint soft tissues in locomotor behavior.

115-3 TSANG, ME*; HAYES, TB; University of California, Berkeley; *tsang.maggie@berkeley.edu*
Variation in the Effects of Endocrine Disruptors on Sex Differentiation in Male African Clawed Frogs (Xenopus laevis)
The herbicide atrazine is one of the most commonly used agrichemicals in the world. It is also a potent endocrine disruptor that is active at low, ecologically relevant doses. Among other mechanisms, atrazine induces aromatase and results in increased estrogen production. Exposure to atrazine during larval development in African clawed frogs (*Xenopus laevis*) results in demasculinized and feminized gonadal and laryngeal morphology. Here, we examined the effects of atrazine and exogenous estradiol on the size of the *dilator laryngis* muscle in male *Xenopus laevis*. Larvae from two different sources of *Xenopus laevis* exhibited dissimilarities in the ratio of females to males produced in response to each treatment, indicating a difference in sensitivity to estrogenic compounds between different sources. Thirty percent of the genetically male larvae from one source (San Diego) developed ovaries in response to estrogen (3 ng/ml), but the second source (Xenopus Express) showed no response. There was no indication of an interaction between atrazine and estradiol, and laryngeal morphology appeared unaffected in both sources. Preliminary observations of female-typical laryngeal morphology in genetically male frogs with testes suggest that there are tissue-specific responses within individuals to endocrine disruptors, prompting further investigation into their causal mechanisms. These data demonstrate the importance of examining variability in response to estrogen and endocrine disruptors in the species, especially if *Xenopus laevis* is to be used as the accepted model for studying endocrine disruption and for predicting impacts on free-ranging amphibians.

P1-264 TUCCI, ER*; HEERS, AM; LENTINK, D; Stanford University; *etucci@stanford.edu*
Parametric Analysis of a Novel Musculoskeletal Avian Flight Model
The avian downstroke and upstroke is primarily powered by two muscles, the pectoralis and supracoracoideus, respectively. The incredible mass-specific power requirements of these muscles have inspired numerous experimental studies and led many authors to suggest that elastic mechanisms play an important role in counteracting the inertial costs of wing motion. However, elastic energy storage and release has not yet been demonstrated, because capturing *in vivo* muscle force production and aerodynamic output is challenging. Here we present a dynamic musculoskeletal model that offers a computational solution for describing the function of each muscle-tendon unit. To create a one-wing musculoskeletal model using OpenSim, we simplified the geometry of a Collared-Dove's (*Streptopelia*) anatomy. The aerodynamic force production of the wing was estimated using a quasi-steady model, and kinematics were based on previously reported data for similar species. To gauge the model's sensitivity to several parameters of interest, we varied these parameters around values estimated from biological data. Additionally, we altered tendon properties and tendon-muscle length ratio to assess whether dove tendons are optimized to reduce the energetic costs of flapping flight. The results may give new ideas to integrate elastic storage into flapping aerial robots to make them more efficient.

P1-108 TUMEY, C. R.*; NOEL, E.; WILLEKERS, S.; COTA, C.; BAKKERS, J.; DAVIDSON, B.; Swarthmore College, Hubrecht Institute; *ctumey1@swarthmore.edu*

Left-right asymmetries in tunicate embryonic gene expression

The processes underlying left-right asymmetry are highly conserved across a wide range of species. Nodal signaling, H+/K+ ATPase-dependent ion flux and ciliary flow are required for lateral asymmetry in both protostome and deuterostome clades yet details regarding how these initial processes lateralize organ morphogenesis remain poorly characterized. We use the invertebrate chordate *Ciona intestinalis* to investigate asymmetric organ development. Previous research indicates that *Ciona* heart asymmetry is dependent on ion flux but does not require Nodal signaling. To understand the link between ion flux and lateralized organ morphogenesis, we have begun to characterize laterally asymmetric gene expression in *Ciona* embryos. By sequencing RNA in thin sections spanning the left-right axis, we have established a list of 19 candidate genes displaying strongly lateralized expression. We have confirmed six of these predicted expression patterns through in situ hybridization. These studies have revealed that many of the candidate genes are expressed in the trunk lateral cell lineage, a group of mesodermal cells that migrate extensively in the larval head and differentiate into blood and muscle. We have also begun to characterize the dependence of these candidate genes on ion flux using the H+/K+ ATPase inhibitor omeprazole. The further characterization of asymmetrically expressed genes should provide critical insights into the molecular mechanisms driving heart and endoderm asymmetry within *Ciona* and vertebrate embryos.

33-5 TUMULTY, J*; FOUILLOUX, C; GOYES VALLEJOS, J; BEE, MA; University of Minnesota, Twin Cities, University of Connecticut; *tumul001@umn.edu*

Predicting and then measuring social recognition decision rules in a territorial frog

Animals must make decisions about how to categorize continuous variation in the world. An example of this is the recognition of familiar individuals. Because signal properties often vary within and among individuals, animals must group perceived variation into individual-specific perceptual categories and discriminate between variation that falls inside and outside of these categories. Such decision rules place boundaries around perceptual categories and are called "just-meaningful differences" (JMDs). To investigate signal variation and JMDs, we examined call variation and decision rules for discriminating between neighbors and strangers in a territorial frog. Male golden rocket frogs (Anomaloglossus beebei) learn to recognize neighbors' calls and show less aggression towards neighbors compared with strangers. We quantified among- and within-individual variation in acoustic properties of calls and predicted an optimal JMD of 6% change for pulse rate and pulse duration, the most individually distinctive properties. We then empirically determined the JMD for pulse rate and pulse duration by testing territorial males in the field with habituation-discrimination playbacks. Males responded aggressively to synthetic calls but eventually habituated. Following habituation, we changed the pulse rate and pulse duration of the stimulus by 0%, 3%, 6%, 9%, and 12%. A 9% change elicited some recovery of aggression, but the largest recovery was observed in response to a 12% change, indicating a JMD at around 9%. These results confirm that male A. beebei can use temporal properties of advertisement calls to differentiate individuals. However, our predicted JMD did not match our empirically determined JMD, highlighting the limitations of analyses of signal variation for inferring receiver behavior.

82-2 TURKO, A; WRIGHT, P; CURRIE, S; BLEWETT, T; TAYLOR, S; ROSSI, G; STANDEN, E*; University of Guelph, Canada, Mount Allison University, Canada, University of Alberta, Canada, Brevard County Environmentally Endangered Lands Program, Melbourne, University of Ottawa, Canada; *estanden@uottawa.ca*

Life history trade-offs depend upon habitat quality in an amphibious mangrove fish

Environmental heterogeneity can result in phenotypic divergence in behaviour, physiology, and life-history strategies. We investigated the consequences of habitat variation on the athletic performance and reproductive investment of the amphibious fish *Kryptolebias marmoratus*. We hypothesized that life-history trade-offs are mediated by environmental quality, such that fish in a relatively well oxygenated freshwater pond would preferentially invest energy in reproduction while those from hypoxic crab burrows would have higher athletic capacity to improve competitive ability. To test these hypotheses we collected wild fish from a freshwater population and a salt water population on Long Caye, Belize. We measured body condition and tested biomechanical performance in water (predator escape response), leaving water (hypercapnia emersion response), and on land (tail-flip jumping). Contrary to our predictions, freshwater fish were both in better condition and showed better endurance compared to their salt water counterparts. Across habitat types our findings suggest that there is no obvious trade-off between athletic performance and reproductive investment in wild mangrove rivulus. Within habitat however, environmental quality matters. Poor quality habitats show no trade-off; fish with high gonadosomatic index are superior athletes. High quality habitats show a clear trade-off where high GSI appears to be correlated with a lower athletic performance. This data suggests that when resources are limited individuals balance their energy allocations while an abundance of resources leads to a greater investment in reproduction.

P2-229 TURNER, ML*; FALKINGHAM, PL; GATESY, SM; Brown University, Liverpool John Moores University; *morgan_turner@brown.edu*

Avian Subsurface Foot Kinematics on Deformable Substrates

A footprint is a record of the complex and dynamic interaction between foot and ground. Both fossil dinosaurian trackways and extant avian experiments have revealed track morphology can vary dramatically from a single individual through different substrates. Substrate consistency affects foot kinematics (motion): most apparent is sinking depth, but other variables such as timing and duration of weight-bearing pedal support are also affected. To explain fossil footprint diversity, how motion varies among and within substrates needs to be understood. Even in living animals, however, documenting foot motion within the substrate is difficult because the distal limb is hidden by opaque sediment. Using marker-based XROMM, we recorded and analyzed 162 steps from 82 trials of three Helmeted Guineafowl (*Numida meleagris*) walking through radiolucent artificial substrates of different consistency (solid, dry granular, firm mud, sloppy mud). Our initial efforts have focused on tracking the path of the tip of digit III, a highly identifiable landmark in many dinosaur tracks, above and below the ground. When viewed only as the tip of digit III, stance on deformable substrates traces a path in the form of a single loop. The geometry of these loops is formed by sinking entry and pull-out exit motions of the whole foot, and is highly variable both across and within substrate types. Importantly, however, kinematic events (eg. first and last contact of opposing foot) contribute to the toe path loop geometry of a single step. Current work is focusing on resolving the relationship between measurable track geometry and kinematics from which the track was formed. This work suggests new methods of extracting depth context, substrate conditions, and kinematic data from dinosaurian tracks.

P2-174 TUTTLE, LJ; ROBINSON, HE; CHAN, C; TAKAGI, D; STRICKLER, JR; LENZ, PH*; HARTLINE, DK; University of Hawaii at Manoa, University of Wisconsin-Milwaukee; *petra@hawaii.edu*

Predator-Prey Interactions between Evasive Copepods and Larval Fish

Calanoid copepods are prime prey of fish larvae, however, often the prey succeeds in escaping from the approaching predator owing to their exquisite detection and evasion capabilities. Using the sub-tropical copepod, *Bestiolina similis* as a model prey, we conducted experiments to assess the capability of adult and copepodid stages to detect and escape from a stealthy predator, the larval clownfish *Amphiprion ocellaris*. The sensitivity of the copepod to an approaching fish was determined using a hydrodynamic model to estimate the rate of water deformation around the copepod as a function of the measured distance to the approaching fish, the fish size, its location, and its velocity. The model was validated by tracking the movement of tracer particles in the bow wave of a swimming fish. We then analyzed the responses of prey to the approach and pre-strike tactics of planktonic-phase clownfish. Escape-directions and -speeds of copepods that successfully detected the predator before its strike were recorded and analyzed. The majority of escapes from such an approach were oriented away (120° to 180° with respect to an approach of 0°), with a few escapes oriented toward but to the side of the fish (0° to 60°). The fewest escapes were directed perpendicular to the approaching fish. Key features of the hydrodynamic disturbance that elicited successful escapes from the approach were identified for both copepodite and adult copepod stages to determine whether there were any differences in sensitivity or escape-direction between these two developmental stages.

131-1 TWINING, CW*; LAWRENCE, P; WINKLER, DW; FLECKER, AS; BRENNA, JT; Cornell University, University of Texas-Austin, Dell Medical School; *cwt52@cornell.edu*

Taking the Short- or Long-chain Route: Conversion Efficiency of Alpha Linolenic Acid to Long-chain Omega-3 Fatty Acids in Aerial Insectivore Chicks

Food availability and quality are both critical for growing young animals. In nature, swallows (*Tachycineta bicolor*) and other aerial insectivores feed on both aquatic insects, which are rich in omega-3 long-chain polyunsaturated fatty acid (LCPUFA) and terrestrial insects, which contain considerably less LCPUFA. Carnivorous mammals and fishes must obtain LCPUFA from diet, as they have lost the capacity to convert the precursor omega-3 ALA into LCPUFA. Thus, the relative value of aquatic versus terrestrial insects depends not only on the fatty acid composition of the prey, but also upon the capacity of consumers to convert ALA into LCPUFA. We used a combination of stable-isotope-labeled fatty acid tracers to ask if, and how efficiently, Tree Swallows can deposit newly synthesized LCPUFA into tissue. Our data show for the first time that Tree Swallows can convert ALA into LCPUFA deposited in liver and skeletal muscle. However, high Tree Swallow demand for LCPUFA combined with low ALA availability in natural terrestrial foods may strain their modest conversion ability. This suggests that while Tree Swallows can synthesize LCPUFA de novo, LCPUFA are ecologically essential nutrients in natural systems. Our findings thus provide mechanistic support for our previous findings and the importance of LCPUFA-rich aquatic insects for Tree Swallows and most likely other aerial insectivores with similar niches.

79-2 TYLAN, C*; ASSIS, B; AVERY, J; LANGKILDE, T; Pennsylvania State University, University Park; *clh319@psu.edu*

Associations between male-typical ornamentation in female fence lizards, and cell-mediated immunity

Sex-linked ornamentation is commonly found in many species, and is often a signal of an individual's fitness. Blue badges on the abdomen and throat are a characteristic male-typical ornamentation of the eastern fence lizard, *Sceloporus undulatus*. Smaller, less intense badges are also sometimes seen on female fence lizards, and their presence is associated with reproductive costs. Some populations of fence lizards exhibit a high prevalence of this female ornamentation, indicating that there should be some advantage to maintaining these badges in certain areas. One such advantage may be improved immune function for the females or their offspring. In this study we assessed the badge size and color saturation of adult female fence lizards, and measured the cell-mediated immune function of their offspring with the phytohemagglutinin skin test. The size and color saturation of maternal badges is associated with differences in offspring immunity, but the impact appears to be greater for male offspring. Our results indicate the potential for an important fitness advantage to females exhibiting male-typical badges, but that this advantages differs somewhat between sons and daughters. This immune up-regulation may be especially important in populations faced with predatory fire ants that frequently cause non-lethal skin wounds; areas in which female ornamentation is more prevalent.

S5-6 TYTELL, ED*; CARR, JA; DANOS, N; COWAN, NJ; ANKARALI, MM; Tufts Univ, Univ San Diego, Johns Hopkins Univ, Middle East Technical Univ; *eric.tytell@tufts.edu*

Using noisy work loops to identify the phase-dependent stiffness and damping of muscle in lampreys

Unlike most manmade machines, animals move through their world using flexible appendages, which bend due to internal muscle and body forces, but also due to forces from the environment. Fishes, in particular, must cope with fluid dynamic forces that not only resist their overall swimming movements but also may have unsteady flow patterns, vortices, and turbulence. We have been characterizing how the muscle tissue itself, due to its own intrinsic properties, is able to respond to perturbations. We have developed a modified work loop protocol to determine how muscle in the silver lamprey, *Ichthyomyzon unicuspis*, responds to perturbations during the swimming cycle. A small section of axial musculature, ~2 myomeres in length, was dissected and used to perform standard in vitro work loops. A 1Hz sinusoidal length change of 6% of the optimal length was imposed on the muscle and both active and passive force were measured. Then, small sinusoidal perturbations at different frequencies are added to the baseline length change. We find that the effective stiffness and damping of muscle varies during the swimming cycle, and that the timing of activation can alter both the magnitude and timing of peak stiffness and damping. The results are analyzed using a new system identification technique based on harmonic transfer functions, which allow us to use these data to predict the muscle function under other conditions. In particular, we are investigating how muscle behaves as part of a feedback loop, when coupled to other muscles and to the body and fluid. Together, these results are starting to produce an integrative understanding of how fish swim effectively in their complex, turbulent environment.

P2-46 UEHLING, JJ*; TAFF, CC; VITOUSEK, MN; Cornell University; *jju8@cornell.edu*

Natal environment influences adult stress responsiveness in free-living birds

An animal's response to environmental stressors may be influenced by a number of factors, including early life conditions, current phenotype, and current environmental conditions. It is well known that environmental conditions experienced during development can influence phenotypes later in life. However, it is unclear how conditions experienced early in life might influence the hormonal mediators of the response to stress across environmental and life stage contexts. Using a long-term dataset from breeding Tree Swallows (*Tachycineta bicolor*) that includes both natal and adult breeding records from the same individuals, we tested if environment during different stages of natal development, current environment and phenotype, or an interaction between natal environment and current environment better explained adult corticosterone levels. We focused on adult corticosterone levels during incubation and provisioning, which are energetically demanding periods during which corticosterone phenotype predicts reproductive success in this Tree Swallow population. Among incubating adults, the year of their birth and the ambient temperature during incubation in their birth year predicted baseline and stress-induced corticosterone, respectively. Among provisioning adults, our top models included adult mass and adult clutch initiation dates, but neither had a strong effect on baseline or stress-induced corticosterone. Our results indicate that natal environmental conditions are important predictors of corticosterone levels during adult incubation, and suggest that short-term changes in weather conditions during early development may have life-long impacts on the ways organisms cope with stress.

S4-10 UL-HASAN, S*; CHENG, H; DOVE, NC; HAGERMAN, L; MONTERROSA, J; PEREZ, T; BIOTA non-profit; *sul-hasan@ucmerced.edu*

BIOTA: A mixed-media, symbiosis in action approach to science communication

BIOTA centers on the scientific definition of symbiosis to both educate and learn from its followers in real time. A non-profit in progress, BIOTA is a team of young professionals from a myriad of backgrounds across the world who have "symbiotically" come together to deliver stories focusing on the environments of our own backyards. We merge art and science to publicly distribute these stories online through short film, pictures, and literature. The Central Valley, for example, is an underrated and underappreciated bioregion of California and yet accountable for most of America's agricultural economy. We spotlight its unique vernal pools and the symbioses of wildlife therein to inform and empower Californians in these locales. With each new story, each new environment, we ourselves gain new knowledge on how to better support these communities. Attendees of this talk can anticipate a new and transferable perspective on strengthening science communication, one that is mindful of social justice and application while promoting critical thinking for a given audience. BIOTA sets a tone for shifting the balance between academics, researchers, and their surrounding neighborhood communities. This approach has awarded our team recognition from Kickstarter, UC Merced's Resource Center for Community Engaged Scholarship, the Leonardo Museum, the Passion in Science "Science Mentorship and Advocacy" Award from New England Biolabs, ValleyPBS, Merced Educational Television, and the University of California Television. The quality of our research as scientists is enhanced when well understood by our public.

90-1 UL-HASAN, S*; MALLOY, ME; HOFMEISTER, JK; SISTROM, MJ; University of California, Merced, Merced, CA, Scripps Institution of Oceanography, UC San Diego, La Jolla, CA; *sul-hasan@ucmerced.edu*

Anthropogenic impacts on the morphology and ecology of venomous marine gastropod species Californiconus californicus

The California cone snail population range, species *Californiconus californicus*, falls within two marine ecoregions increasingly subject to negative anthropogenic impacts over the past century. Despite its trophic significance as a top marine invertebrate predator and extreme generalist, surprisingly little is known about *C. californicus* ecology. We measured the length, width, aperture width, and thickness of over 1800 adult *C. californicus* shells from historical collections and compared transect data between Marine Protected Areas (MPAs) and non-MPAs to (1) determine if human recreation and urbanization is negatively correlated with *C. californicus* population density and (2) create an ecological niche model conscious of the Anthropocene. Our current analyses demonstrate statistically less *C. californicus* in non-MPAs compared to MPAs, with deeper analyses of biotic and abiotic influences underway. We also see *C. californicus* shell morphology follows Bergmann's rule, contingent with findings for species within the same range. Several previous studies in the scientific community have shown variation in marine gastropod shell morphology to be associated with adaptation. These findings give us reason to hypothesize *C. californicus* shell morphology responds to rising, anthropogenic-induced temperatures by decreasing shell thickness and forming more narrow spires to release excess heat. The results from this work will serve as a reference for others conducting research in the California-Baja intertidal and subtidal zones, and emphasize the importance of maintaining species distribution models for experimental and conservation purposes.

P3-84 UNFRIED, LN*; CHAMPAGNE, AM; BANDOLI, JH; University of Southern Indiana; *lnunfried@eagles.usi.edu*

Advances in the timing of reproduction in two species of cavity nesting birds in response to climate change

The timing of breeding is critical in determining reproductive success. As global temperatures have increased in recent decades, many animals have modified their breeding behaviors. Among birds, some species have advanced the timing of reproduction in accordance with temperature increases, whereas other species have failed to adjust breeding time, resulting in mistimed reproduction. We analyzed 25 years of nesting data from Eastern Bluebirds (*Sialia sialis*) and Carolina Chickadees (*Poecile carolinensis*), from 38 nest boxes on the University of Southern Indiana campus in Evansville, IN. Between the years of 1973 and 2017, the onset of breeding, measured as the date of the first egg laid by each species, advanced by more than 7 days in bluebirds and 11 days in chickadees. In both species, the advancement in breeding correlates with average surface temperature at the time of breeding. This correlation suggests that Eastern Bluebirds and Carolina Chickadees can adjust breeding phenology based on proximate cues, and may be able to adjust to a changing climate.

76-7 USHERWOOD, JR*; SELF DAVIES, ZT; SMITH, BJH; The Royal Veterinary College; *jusherwood@rvc.ac.uk*

Work minimization accounts for footfall phasing in slow quadrupedal gaits, and phases used by primates allow more controlled forefoot placement.

Quadrupeds, like most bipeds, tend to walk with an even left/right footfall timing. However, the phasing between hind and forelimbs shows considerable variation. Here, we account for this variation by modeling and explaining the influence of hind-fore limb phasing on mechanical work requirements. These mechanics account for the different strategies used by: 1) slow animals (a group including crocodile, tortoise, hippopotamus and some babies); 2) normal medium to large mammals; and 3) (with an appropriate minus sign) sloths undertaking suspended locomotion across a range of speeds. Phases predicted to be particularly costly are not observed in nature. While the unusual hind-fore phasing of primates does not match global work minimizing predictions, it does approach an only slightly more costly local minimum. Further, modeled instants of the 'toppling' motion in the gait cycle with normal walking phases occurs just prior to forefoot placement, an observation consistent with footfall phasing in grazing livestock. In contrast, primate phases result in these toppling instants instead occurring just prior to hindfoot placement, with potential advantage in terms of controlled forefoot placement on narrow or unpredictable substrates.

46-6 UYENO, TA*; CLARK, AJ; Valdosta State University, College of Charleston; *tauyeno@valdosta.edu*

Baggy Skins with Benefits: How Loose Fitting Integuments can be Adaptive

Organisms that rely on internal support structures often possess deformable body coverings. Such integuments found in pressurized, soft-bodied invertebrates can be **tight** fitting and feature tensile fibers that constrain deformation. In many vertebrates, a tight body covering may also serve to store elastic energy or transmit force generated by muscles to locomotory structures. Our understanding of the function of **loose** fitting body coverings is less clear as there may be multiple, varied, and interrelated benefits. Our preliminary survey suggested that the function of loose skins often falls into one or more of four distinct categories: to ensure maximal range of motion; to maximize surface area; for puncture resistance and wound closure; and to lubricate. Biological examples of loose skins for each category include: the wrinkly skins of naked mole rats do not impede joint motion while turning in tunnels; giant salamanders can uptake oxygen across the large surface area represented by their loose skins; the loose belly skin of large felids prevent damage from ungulate prey hoof kicks and loose octopus and rabbit skin tends to pucker around a cut in order to seal it; the folds of chameleon tongue skin reduces friction during ballistic protraction. To validate this categorization scheme, we investigate an especially loose-skinned animal as a model organism: the hagfish. Using histology, 3D reconstructions, high-speed videography, and material testing of the skin and the body core, we find that loose skin may be an adaptation that A) allows the body core to form tight, yet sliding, knots to clean off slime, feed, and escape, B) increases the surface area over which cutaneous nutrient uptake may occur and C) improves puncture resistance by increasing the energy required to pierce the skin.

P2-116 VACCARO-GARSKA, KM*; KOCOT, KM; JANOSIK, AM; University of West Florida, University of Alabama; *kmv12@students.uwf.edu*

Sexual dimorphism in Coronis scolopendra (Stomatopoda): do males and females see the world differently?

Known for their unique visual capabilities, stomatopods, commonly called mantis shrimp, have one of the most complex visual systems in the animal kingdom. The eyes of an individual stomatopod can contain up to 16 classes of photoreceptors; in contrast, human eyes contain 4. These photoreceptors contain proteins called opsins, light-sensitive proteins that mediate the conversion of a photon into an electrochemical signal. Different opsins are sensitive to different wavelengths of light, enabling stomatopods to see a wide range of wavelengths. *Coronis scolopendra* is a spearing lysiosquilloid, and the only stomatopod species that exhibits drastic sexual color dimorphism. Females are dark brown, while males are light tan. Based on this unusual coloration and complex visual system, we hypothesized that sexual dimorphism also plays a role in opsin expression in this species. Specifically, males and females require differently tuned opsins to recognize individuals of the same and opposite sex. To this end, we are comparing gene expression in male and female *C. scolopendra* eyes. Specimens were collected from St. Andrews Bay, FL. RNA was extracted from eyes of three males and three females, sequencing libraries were prepared for each individual, and sequencing was conducted using an Illumina HiSeq 4000 generating 85-110 million reads per sample. Sequences were assembled de novo using Trinity. The assembled sequences will be annotated and opsin expression will be compared between male and female transcriptomes. This will be the first study on a sexually dimorphic stomatopod examining sexual dimorphism at a molecular level.

P1-48 VALDEZ, J; PORTER, ML; BOK, MJ; WOLF, JB; CRONIN, TW*; UMBC, University of Hawaii, Bristol University, UK; *cronin@umbc.edu*

Sequence, Diversity, and Expression of Visual Opsins in the Stomatopod Squilla empusa

MSP analysis of isolated photoreceptors from the Atlantic stomatopod species *Squilla empusa* reveals that all photoreceptors absorb light maximally at 507 nm. This suggests that a single visual pigment is present in all retinal photoreceptors. However, multiple distinct opsin transcripts, encoding the protein component of the visual pigment, have been isolated. Six opsin sequences have been published and additional ones obtained by transcriptomics. Phylogenetic analysis reveals that all these opsins localize to several major arthropod middle/long wavelength opsin clades. In this study, we examined the expression of opsins in the retina using *in situ* hybridization and use bioinformatics and structural modeling to analyze amino acid sequences and predict 3D structures of the visual pigments to search for potential functional or spectral differences among the various expressed opsins. *In situ* hybridization of *S. empusa* retinal sections was done using riboprobes that target the 3'UTR of transcripts of two specific opsin genes, Se5 and Se6. The results suggest co-expression of multiple opsins in the same regions of the retina, and also suggest possible preferential expression of opsin Se6 in a subset of photoreceptor cells in the peripheral regions of the retina. Amino acid sequence and structural analysis suggests that spectral differences between opsins Se5 and Se6 are unlikely, due to very high sequence homology, particularly in the amino acids in close proximity to the chromophore binding pocket. Taken together, these data suggest that the monochromatic stomatopod *Squilla empusa* possesses a higher level of molecular complexity than predicted, but the exact function of multiple opsin expression remains unclear.

104-7 VALENTINE, S. A. *; MCCAULEY, D. J. ; ATWOOD, T. B. ; Utah State University, Univ. of California, Santa Barbara; *shaleyvalentine@gmail.com*

Extinction Vulnerability of Different Trophic Levels in Mammalian Species across Time

Humans have played a significant role in the biology of planetary species extinctions from the Pleistocene to the present. Despite the diverse causes of these human-associated extinctions, extinction patterns are not random. Recent studies have shown that extinction risk may be linked to specific life history or ecological traits that make a species inherently susceptible to human activities. How this relationship may have changed over the course of human history, however, is not well known. Here, we examined how human-associated mammalian extinctions at different trophic levels vary from the end of the Pleistocene to present day. To execute these comparisons, we grouped species into trophic levels, assigned them a threat assessment, and used random simulations to investigate whether extinction risk patterns in trophic levels over time deviated from null model predictions. We found that, overall, herbivores were consistently overrepresented in mammalian extinctions, but that the proportion of extinct or threatened herbivores declined over time. Of the Pleistocene extinct species, more herbivores and fewer predators and omnivores went extinct than predicted in the null model. This general pattern persisted in analyses of mammalian species that have recently gone extinct and that are presently threatened by extinction. The percent of extinction prone herbivores has declined over time, suggesting human impacts may be more equally spread across trophic levels in present time.

P2-14 VALLE, S*; KIEFFER, N; EAGLEMAN, D; DEVICHE, P; Arizona State University; *srvalle@asu.edu*

Effects of Altered Energy Balance on Reproductive Development in the Male House Finch (Haemorhous mexicanus): The Role of Metabolic Fuels

Reproductive success requires that individuals acquire sufficient energy resources. Altering energy homeostasis through restricting food availability or increasing energy expenditure (e.g., locomotion, thermoregulation) inhibits reproductive development in multiple avian species, but the nature of the energy-related signal mediating this effect is unclear. To investigate this question, we examined reproductive and metabolic physiology in male House finches under 1) moderate food restriction (FR), and 2) heat stress (HS), in which birds were we exposed to a high ambient temperature cycle (85-100°F) compared to a control group (70-85°F). We hypothesized that either FR or HS inhibits reproductive development through lowering available metabolic fuel, specifically plasma glucose (GLU) and free fatty acids (FFA). Following FR for 4 weeks, finches lost body mass and experienced a 90% reduction in testis mass compared to *ad libitum*-fed birds. Plasma GLU was unaffected by food availability. Plasma FFA, however, were higher after 3 days of FR, potentially indicating increased FFA utilization. In a separate group of finches, 4 weeks of exposure to HS resulted in reduced body mass and voluntary food consumption, as compared to control birds. Testis mass decreased by 70% in HS birds, but this treatment did not influence plasma GLU or FFA. These studies are among the first to highlight the potential role of metabolic fuel in mediating inhibitory effects of FR on the reproductive system and to demonstrate a negative effect of HS on reproductive development in a wild bird. Further studies are needed to clarify the role of metabolic mediators and their involvement under different conditions of energy availability and demand.

136-2 VALLOMPARAMBATH, R*; GOPINATHAN, A; YEAKEL, J; Univ. of California, Merced; *ritwika@ucmerced.edu*

The Fitness Trade-offs of Predation: When to Scavenge and When to Steal

Organisms make a variety of decisions while foraging, each with different costs and benefits. For example, predator behaviour during foraging can fall on a continuous spectrum between hunting and scavenging. In this study, we examine the behaviour of a group of foragers that can actively hunt for prey, or scavenge from the foils of a fixed pool of predators, either by eating leftovers (passive scavenging) or by stealing from a predator (active scavenging). To do this, we employ stochastic dynamic programming which enables us to construct a deterministic matrix of decisions and associated fitness values for a set of potential behaviours (Clark and Mangel., 2000). This approach is centred around finding consumer behaviours that maximise fitness. Our results suggest that there are well-defined parameter regimes where each foraging strategy maximises fitness, and that risky behaviour (active scavenging) becomes a viable choice when costs associated with hunting and scavenging are comparable, or when the mortality associated with active scavenging is low enough. We also see that the parameter space that allows for active scavenging is considerably smaller than that of both hunting and passive scavenging, as one would expect. We then generalise this model in terms of organismal body mass so that it can be applied to real-life systems to determine the relationship between body-size classes and different predatory behaviours, and to better understand trade-offs in decision-making associated with body-size limitations.

46-3 VAN BREUGEL, F*; DICKINSON, M; University of Washington, Caltech; *florisvb@gmail.com*

Super-hydrophobic diving flies and the kosmotropic waters of Mono Lake

The alkali fly, *Ephydra hians*, has a remarkable natural history in which it deliberately crawls into the alkaline waters of Mono Lake to feed and lay eggs. Despite Mark Twain's charismatic descriptions of these creatures in his book Roughing It over 150 years ago, we still do not understand the physics and chemistry surrounding their remarkable adaptations. *"You can hold them under water as long as you please--they do not mind it--they are only proud of it. When you let them go, they pop up to the surface as dry as a patent office report, and walk off as unconcernedly as if they had been educated especially with a view to affording instructive entertainment to man in that particular way."* The diving flies are protected by an air bubble that forms around their super-hydrophobic cuticle upon entering the lake. To study the physical mechanisms underlying this process, we measured the work required for flies to enter and leave various aqueous solutions. Our measurements show that it is more difficult for the flies to escape from Mono Lake water than fresh water, due to the high concentration of Na_2CO_3 which causes water to penetrate and thus wet their setose cuticle. Other less kosmotropic salts do not have this effect, suggesting that the phenomenon is governed by Hofmeister effects as well as specific interactions between ion pairs. Compared to six other species of flies, alkali flies are better able to resist wetting in a 0.5M Na_2CO_3 solution. This trait arises from a combination of factors, most notably a denser layer of setae on their cuticle. Although superbly adapted to resisting wetting, alkali flies are vulnerable to getting stuck in natural and artificial oils, including dimethicone, a common ingredient in sunscreen and other cosmetics. Mono Lake's alkali flies are a compelling example of how the evolution of pico-scale physical and chemical changes can allow an animal to occupy an entirely new ecological niche.

P3-96 VAN DER WALT, M*; FRENCH, SS; School of Veterinary Medicine, Washington State University, Pullman WA, Department of Biology and Ecology Center, Utah State University, Logan, UT; *Marilize268@gmail.com*

Measuring Reproductive Function and Stress in Polar Bears (Ursus maritimus) Using Hair and Serum Hormone Concentrations

Polar bears rely on sea ice for reproductive behaviors and food, and progressive sea ice decline has had severe impacts on the health and reproductive success of polar bears. This environmental stressor may be causing physiological changes that can be measured via endocrine function: cortisol is an energy mobilizing hormone and indicative of stress, and testosterone (males), and estradiol and progesterone (females) can be used to measure reproductive function. While fecal and serum samples have previously been used, hair may be a useful alternative, being less invasive to obtain, and theoretically providing a long-term average of the previous year's hair growth, thus being unaffected by capture stress. Hair and serum samples were collected from free-ranging polar bears, validated, and analyzed for stress and reproductive hormones via radioimmunoassay. We found that hair and serum estradiol concentrations were positively related, as were hair progesterone and estradiol, progesterone and cortisol, and testosterone and cortisol. These results suggest that hair may be a good predictor of serum estradiol concentrations, and that there are significant interactions among stress and reproductive functions that are measurable in hair. Hair might therefore be a useful tool for understanding the effects of sea ice decline on reproductive function and the role of stress in these changes, thereby playing a critical role in conservation efforts for the species.

P1-91 VAN NEST, BN*; OTTO, MW; MOORE, D; Case Western Reserve University, Corblu Ecology Group, East Tennessee State University; *bnv11@case.edu*

Effects of Circadian Time-Memory on Foraging Recruitment in Honey Bees

Forager honey bees (*Apis mellifera*) are able to remember both the location and time of day food is collected. Foragers reconnoiter a food source at the appropriate time on subsequent days in the absence of food and even after several days of inclement weather. This food-anticipatory activity is under circadian control and enables the forager to synchronize its efforts with nectar secretion rhythms of flowers. This also alleviates the need to rediscover productive food sources each day. We previously showed that foragers with greater amounts of experience exploiting a food source are slower to abandon that source after it ceases to be productive. Here, we ask if such foragers are less recruitable to another food source that is available at the same time of day. We simultaneously trained two groups of foragers from a single hive to two separate feeders. After five days of training, one feeder was shut off. The second feeder continued being productive four more days. Our results show that (1) the majority of visits to both feeders occurred during the original training window and (2) high-experience foragers were more likely than low-experience foragers to maintain fidelity to their original source and resist recruitment to the alternative source. In light of our recent findings that a large proportion of foragers appear to maintain multiple time-memories for multiple food sources, it was also interesting to find that (3) high-experience foragers were more likely than low-experience foragers to be recruited to the alternative source while continuing to reconnoiter their original source, thus managing simultaneous, overlapping time-memories.

21-3 VAN ORDEN, TONYA; Mercer Island School District; *tonya.vanorden@mercerislandschools.org*

Supporting the Problem Solving Skills of Gifted Students Through the Use of Social Stories

Neurodiverse students include students with autism spectrum disorder, ADHD, and/or students identified as "gifted". Neurodiverse students tend to need support with executive function skills, and gifted students are no exception. This mixed methods action research study investigated whether social stories, an instructional intervention used with autism spectrum disorder students, could be used to support the executive function skill of problem solving in a sample of 25 gifted middle school students. Students' use of help-seeking questions was observed pre and post intervention as a problem-solving indicator and students' perceptions of their help-seeking question use were also qualitatively explored. The results showed a 60 percent increase in help-seeking questions post intervention, as well as evidence indicating that students understand questions help them deepen knowledge and pre-plan their actions. Student-initiated questions varied in complexity and type, but overall indicated a readiness to use information. Social story development provided intentional rehearsal and connection between problems and solutions for students and had a clear effect on student problem solving skills. Therefore, social stories can be used to help gifted students develop the executive function skills they need to function in rigorous academic environments.

P2-210 VAN WASSENBERGH, S*; AERTS, P; Muséum National D'Histoire Naturelle, Paris, Univ. of Antwerp, Belgium; *svanwassenbergh@mnhn.fr*

Optimization of a new, biplanar X-ray video system for analyzing 3D kinematics and hydrodynamics of animals

A biplanar, high-speed X-ray videography set-up for zoological research (named $3D^2$YMOX) was recently installed at the University of Antwerpen in Belgium. The set-up includes two Phillips Imagica image intensifiers, each coupled to a 4 megapixel, square-sensor Photron high-speed camera. We report tests of its performance: targeted volumes, spatial resolutions, and spherical marker tracking accuracies. A solution is presented to perform flat field corrections by using Photron's pixel gain calibration function to equalize pixel intensities of an empty scene. In this way, the full dynamic ranges of the camera sensors can be used across the image field. Tests were performed with small particles (< 1.5 mm diameter) with a radio-opaque core that are neutrally buoyant in water. Such particles can be used to visualize flows of water in regions that have no optical access with standard cameras, e.g. on the inside of mouth cavities of aquatic animals.

87-3 VAN WERT, JC*; ROGERS, LJ; MENSINGER, AF; Marine Biological Laboratory, University of Minnesota Duluth; *amensing@d.umn.edu*

The Effect of Self-generated Movement on Lateral Line Sensitivity in the Toadfish, Opsanus tau

The mechanosensory lateral line in fishes detects movement, vibration, and pressure gradients in water. However, the effect of self-generated movement on the sensitivity of the lateral line remains largely unknown. Microwire electrodes were inserted into the anterior lateral line nerve of toadfish using an implantable micromanipulator which allowed neural activity to be monitored for up to two weeks post-implant. Experiments measured neural response to external stimulus during forward movement. Freely swimming fish remained sensitive to stimuli produced by a vibrating sphere indicating that the lateral line can detect external stimuli during movement. Additionally, moving fish were able to detect the stimuli generated by the tail motions of a robotic fish. There was no evidence of efferent modulation during forward movement and efferent nerves did not show increased firing during swimming. While efferent modulation or central filtering of self-generated movements had previously been postulated as mechanisms to allow free swimming fish to continue to detect outside stimuli, the current experiments show that at the swim speeds observed, the mechanosensory lateral line can sense external stimuli without modulation or filtering.

120-5 VANDENBROOKS, JM*; PARKER, G; ZAFFINO, A; HARRISON, JF; Midwestern Univeristy, Midwestern University, Arizona State University; *jvandenbrooks@midwestern.edu*

Life history traits affect the response of insects to variation in atmospheric oxygen

Atmospheric oxygen has the potential to affect the physiology, development and evolution of insects. However, insects demonstrate a wide range of responses to variation in developmental, chronic, and acute oxygen exposures. To better understand these differential responses, it is important to consider the life history traits of these organisms. Investment in different life history strategies involves a series of tradeoffs that may make organisms more or less susceptible to atmospheric oxygen. To begin to examine these tradeoffs, a series of experiments have been done that manipulate these life history traits and then measure the responses of those insects to variation in atmospheric oxygen. *Manduca sexta* lines artificially-selected for high growth rate and large body size were more susceptible to oxygen variation than those selected for smaller body size and slower growth rates. *Zophobas morio* that were reared individually and experienced faster growth rates were more susceptible to oxygen during the juvenile phase, while those that were reared in crowded conditions and experienced longer development times showed a stronger effect of oxygen on adult lifespan. When comparing *Blatella germanica*, a small roach species to *Gromphadorhina portentosa*, one of the largest roach species, *G. portentosa* showed a larger effect of oxygen on body size, while *B. germanica* showed a larger effect of oxygen on growth rate suggesting differential energy investment in these two species. In sum, these data suggest that life history traits determine tradeoffs between investment in growth and development and the ability to deal with oxygen stress throughout the lifespan of the organisms.

P1-147 VANGORDER-BRAID, J/T*; SIRMAN, A/E; HEIDINGER, B/J; North Dakota State University; *jennifer.vangorderbr@ndsu.edu*

Does TA-65 influence telomere length and loss during early life in house sparrows (Passer domesticus)?

Understanding the mechanisms that contribute to variation in longevity is critical to evolutionary ecology and biomedicine. Telomeres, protective caps at the end of eukaryotic chromosomes that enhance genome stability, may be one mechanism that is important. In the absence of restoration, telomeres shorten during cell division and in response to stress and limit cellular lifespan. Once telomeres reach a critically short length, cells stop dividing and begin to senesce. Recent evidence shows individuals with longer telomeres during early life live longer. However, whether telomeres are causally related to longevity, or simply a biomarker, or both is currently unknown and manipulation of telomere length will be essential to disentangle these possibilities. Telomeres can be extended by telomerase, an enzyme that is expressed during embryonic development and down-regulated in most somatic tissues soon after birth or hatching. Previous research suggests that TA-65, a plant extract from the *Astragalus membranaceus* root, lengthens telomeres by increasing telomerase expression. To investigate the causal role of telomeres in early life, we experimentally manipulated TA-65 in growing free-living house sparrows (*Passer domesticus*) and examined the effect on telomere length and loss. Nests were randomly assigned to either a control or experimental treatment group. Between days 2-10 post-hatch, experimental nestlings received daily oral doses of TA-65 in sterile water and control nestlings received daily oral doses of sterile water. Blood samples were collected from all of the nestlings on days 2 and 10 to measure telomere length and loss Growth measurements were collected every 3 days. We predicted that experimental nestlings would experience less telomere loss and have longer telomeres than controls.

P2-224 VARGEESE, JJ*; ORSBON, CP; ROSS, CF; GIDMARK, NJ; Knox College, University of Chicago; *jjvargeese@knox.edu*

Large bite forces maintained across gapes may evade length-tension constraints due to the muscular dynamics in the masticatory system of the primate Macaca mulatta.

Bite force is an important performance variable for animals and is comprised of muscular force input (by the jaw-closing muscle) and jaw mechanics (skeletal morphology). Muscle force input is dynamic across jaw positions (gapes) due to the physiological constraints of skeletal muscle. We examined how the force-length relationship of a jaw-closing muscle (superficial masseter) relates to bite force across various gapes in two Rhesus Macaque (*Macaca mulatta*) monkeys during supra-maximal stimulation. The female we tested varied in biting force by 37% across gapes, whereas the male varied by 25% across gapes. This variation in muscular input is surprisingly small, given 50% muscle-tendon-unit (MTU) length change in the female and 55% MTU length change in the male. We found that intermediate gape widths produced the highest bite force, and extreme gapes (large and small) produced lower bite forces. We implanted radiopaque markers in the masseter muscle, skull, and mandible of each individual and filmed with x-ray video during the experimental stimulation events for XROMM analysis. We found that markers within the muscle bulged laterally as force increased. At higher gapes, the muscle fibers were more in line with the line of action of the muscle-tendon unit (which we attribute to a decrease in pennation angles) and produced less lateral bulging. We propose that rotation of jaw muscle fibers is a product of both active (fiber shortening and contractile force) and passive (elastic behavior of connective tissue and aponeuroses) mechanisms.This fiber rotation allows *Macaca mulatta* to bite at near optimal force levels across a wider range of gapes than would otherwise be possible.

P3-159 VARNEY, RM*; SPEISER, DI; KOCOT, KM; Univ. of Alabama, Univ. of South Carolina; *rvarney@crimson.ua.edu*

The genome of the chiton Acathopleura granulata: preliminary work toward understanding biomineralization of teeth as tough as tank armor

Like most molluscs, chitons (Polyplacophora) have a toothed tongue-like organ called a radula, which they use to feed by rasping food from hard substrates. The teeth of the radula form within an organic matrix of chitin and protein and develop a core of apatite. Unlike most other molluscs, chiton teeth are further hardened with a coating of iron in the form of magnetite. These remarkably strong teeth have an incredible abrasion resistance comparable to that of tank armor and thus are of great interest to researchers in fields ranging from evolutionary biology to biomechanics, but the genomic basis of iron biomineralization in chitons is unknown. To elucidate this process, we are sequencing a draft genome for *Acanthopleura granulata*, which will join fewer than ten currently sequenced molluscan genomes and represent the first aculiferan. Leveraging a high-quality chiton genome, we will identify candidate gene families involved in iron biomineralization and reconstruct their evolutionary history. Further, we will investigate the genomic basis of chiton radula biomineralization by examining differences in gene expression among four regions of the *Acanthopleura* radula: the anterior-most segment with fully mineralized but also abraded teeth, a second segment with teeth mineralized with iron, a transitional segment in which iron is first deposited, and a posterior segment comprised of clear teeth with no iron present. A chiton genome will inform all studies of molluscan evolutionary biology, while comparative transcriptomic work on the radula will link phenotypes of interest in material science to corresponding genotypes. Taken together, this work will offer insight into an understudied group of molluscs and their unique physiology.

P3-45 VASADIA, D*; PLACE, SP; California State University, Sonoma; *vasadia@sonoma.edu*

Characterization of thermoregulated miRNAs and their role in the heat shock response of the Antarctic notothenioid fish, Trematomus bernacchii

Antarctic Notothenioids are known to display a narrow thermal tolerance window and their reduced capacity to acclimate to a warming ocean is exacerbated by the loss of the heat shock response (HSR) that can help to mitigate the cellular level effects of elevated ocean temperatures. The lack of the inducible HSR has been extensively investigated at the transcriptional level in several species, yet we have little insight into the mechanism underlying this disruption in mRNA regulation. In particular, the role of post-transcriptional regulation of mRNA stability by microRNAs in the HSR has received little to no attention, especially in polar fish. MicroRNAs (miRNAs) are small (~22 nucleotides), evolutionarily conserved, non-coding RNAs that predominantly downregulate gene expression in a sequence specific manner. The aim of this study is to annotate miRNAs from the transcriptome of *Trematomous bernacchii* and characterize their regulatory role during a thermal stress event. To this end, our deep sequencing analysis identified a total of 125 different miRNAs in *T. bernacchii* gill tissue, of which 19 displayed differential expression during an acute thermal stress. We further assessed the biological function of these thermoregulated miRNAs using computational prediction programs to identify putative gene targets followed by analysis of the corresponding changes in transcript abundance. This integrated DE analyses of miRNAs and mRNAs in the *T. bernacchii* transcriptome provides some of the first insights into the role miRNAs play during a cellular stress response of an extreme stenotherm.

47-3 VASQUEZ, M. C.*; TOMANEK, L.; Cal Poly San Luis Obispo; *mcvasque@calpoly.edu*

Exposure of Mytilus mussels to Multiple Stressors Reveals Non-predictive Interaction Effects

Understanding physiological tolerances of marine organisms to environmental stress is key to predicting species adaptability in a changing global climate, and when investigated, is most accurate under a multiple-environmental stressor approach. Congeners of the intertidal mussel genus *Mytilus* vary in their physiological tolerances to environmental stress. *M. galloprovincialis*, an invasive species from the Mediterranean, is overall more stress tolerant and can withstand elevated heat exposure, but it is vulnerable to hypo-salinity, while the native Pacific coast *M. trossulus* is more tolerant to hypo-saline conditions but vulnerable to heat stress. Recent findings suggest that sirtuins, a group of NAD+ dependent deacetylases, influence the environmental stressor tolerances in these two mussel species. Therefore, the purpose of this study was to investigate the combined effect of hypo-salinity and aerial heat stress on the proteome of *M. galloprovincialis* and *M. trossulus* while also investigating the role of sirtuins in influencing stress tolerance. Mussels were acclimated to tidal and circadian cycles for 3 weeks after which mussels were exposed to fully factorial combinations of salinity (34 or 29 ppt), aerial heat (18 or 32°C) and sirtuin inhibition (+/- suramin and nicotinamide) over the course of a 6 h high tide and 6 h low tide event. Gill tissue was collected after each stress exposure and following a 6 h recovery in control conditions (34 ppt, 18°C and no sirtuin inhibition). Significant two-way and three-way interactions were identified that depict a complex response to combined stressor conditions.

79-6 VAZIRI, GJ*; ADELMAN, JS; Iowa State University; *gvaziri@iastate.edu*

Host-Parasite Interactions and the Acute Phase Immune Response in a Songbird

Co-infection with helminth parasites (e.g. gut worms) and microparasites (bacteria or viruses) is often the natural state for wild animals. Although murine models have shown that gut helminths can bias immune responses away from inflammatory processes, few studies have examined the role that helminths play modulating immunity in free-living, wild vertebrates. Here, we used anthelminthic drugs to treat free-living song sparrows (Melospiza melodia) for helminth infections ("de-wormed" birds) and measured markers of systemic inflammation (heterothermia and activity level) to an immune challenge induced using lipopolysaccharide (LPS), a nonreplicating cell-wall component of gram negative bacteria. We attempted two non-invasive methods of confirming helminth infection status, fecal flotations and 18S amplicon sequencing. Skin temperature and activity level were monitored remotely using automated radio telemetry in the field. Because helminths can reduce inflammation, we predicted that in comparison with control birds (birds not treated for helminth infection), de-wormed birds would be less active and display higher fevers when challenged with LPS. In contrast, initial analyses suggest that de-worming had no effect on thermoregulation, and that LPS-injection decreased birds' activity regardless of anthelminthic treatment. These results suggest that natural helminth infection may not bias bird immune response away from whole-body inflammation, though such patterns may depend on tissue tropisms and other characteristics of specific co-infecting organisms.

P1-220 VEGA, J*; IVANOV, BM; JOHNSON, MA; Trinity University; *jvega1@trinity.edu*

The Evolution of Muscle Size: Fiber Number, Fiber Size, and Behavior in Anole Lizards

Muscles that are used frequently are often larger than muscles that are used rarely. A muscle may develop or evolve a larger size as the result of larger muscle fibers, more muscle fibers, or a combination of larger and more fibers. Further, larger muscles may be associated with more frequent behavioral use. The muscles used in lizard copulation provide an excellent opportunity to address these questions. In this study, we examined the retractor penis magnus (RPM) muscle of 24 species of anoles from the Caribbean and southeastern United States. This muscle retracts the male hemipenes back into the tail after copulation. We predicted that larger RPM muscles evolved in association with more and/or larger muscle fibers, and that the number or size of fibers in the RPM evolved in association with copulation frequency. For each species, we measured the cross-sectional area and number of fibers in the RPM, the total cross-sectional area of the RPM, snout-vent length (SVL), and the rate of copulation behavior during focal observations in the field. We found that larger-bodied species have more RPM fibers, species with larger RPMs have more fibers, and that there is no trade-off between the size and number of RPM fibers. We also found that across species, copulation is not correlated with RPM fiber size or number. Together, these results suggest that RPM muscle size evolves as a function of more and larger fibers, but not behavioral use of the muscle.

127-2 VEGLIA, AJ*; HAMMERMAN, N; RIVERA, C; LUCAS, M; GALINDO ESTRONZA, A; CORGOSINHO, P; SCHIZAS, N; Unv. of Puerto Rico, Mayaguez; *alex.veglia@upr.edu*

Characterizing population structure of coral associated crustaceans from mesophotic and shallow habitats in the Caribbean

The formation of symbiotic relationships is a most common adaptation among marine crustaceans forming both obligatory and non-obligatory (facultative) dependencies with their host. How the obligatory nature of these symbioses influences the invertebrates population structure has only been mildly addressed in the literature. Here we investigate and compare the population structure of an obligate symbiont (Ceratoconcha domingensis; a barnacle) and a facultative symbiont (Laophontella sp.; a harpacticoid copepod) of the coral Agaricia lamarcki from shallow and mesophotic habitats. Barnacle specimens were collected from shallow (<30 m) and deep (>30 m) colonies of A. lamarcki in La Parguera and Guanica¸ Puerto Rico. Laophontella sp. was collected from mesophotic (>50 m) A. lamarcki colonies in El Seco, Vieques and mangrove sediments (<3 m) in Curacao. The Cytochrome Oxidase Subunit I gene was amplified and sequenced for barnacle (n=93) and copepod (n=54) specimens. Molecular analysis revealed no population structure between deep and shallow barnacle populations within La Parguera and Guánica (ΦST = 0.00444). Meanwhile, Laophtontella sp. was shown to have significant structure between the mesophotic reef of El Seco and mangrove sediments of Curacao (ΦST = 0.28). Interestingly, the El Seco and Curacao sample sets had three shared haplotypes. Shared haplotypes were unexpected between these sample localities based on the general life history of harpacticoid copepods and the geographic distance between locations. Four outlier sequences were identified within El Seco sequences potentially representing three different species. The identification of potentially three cryptic species is proof of the current need for a deeper investigation into the meiofaunal diversity associated with mesophotic ecosystems.

P1-127 VELHAGEN, WA; Caldwell University; *wvelhagen@caldwell.edu*

Development of the Tongue and Tongue Sheath in Colubrid Snakes

I described the development of the tongue and tongue sheath in sectioned embryos of colubrid snakes that had been staged following the criteria of Zehr (1962). Most specimens belonged to the thamnophiine genera *Nerodia* and *Storeria*. There was a general pattern with some variation among species. Before stage 29, the tongue is an undifferentiated elevation in the floor of the oral cavity. By stage 29, the anterior end of the tongue is forked and detached from the floor of the mouth; two bundles of longitudinal muscles have begun to differentiate. By stage 32, the tongue sheath has begun to form and extend caudally; the verticalis and transverse muscles have differentiated. At stage 34, the tongue sheath has extended posterior to the skull. In later embryonic stages, an additional layer of tissue encircles the caudal tongue sheath. By the last embryonic stage, the histology of the tongue is very similar to what has been described in adults.

120-2 VELOTTA, JP*; SENNER, NR; WOLF, CJ; SCHWEIZER, RM; CHEVIRON, ZA; University of Montana; *jonathan.velotta@gmail.com*

Convergent Evolution of Physiological and Genomic Responses to Hypoxia in Peromyscus Mice

Convergent evolution is the process by which similar traits arise independently under similar selective pressures. Understanding the mechanistic basis of convergence is a critical step towards understanding the repeatability and predictability of evolution. We used mice in the genus *Peromyscus* to explore the mechanistic basis of convergent evolution. Across North America, multiple species of *Peromyscus* have independently invaded high-altitude environments, which are characterized by severe and unremitting hypobaric hypoxia. Correspondingly, studies of the unique physiologies of high-altitude animals have provided clear examples of local adaptation and convergent evolution. However, it is yet unclear whether convergent solutions to hypoxia arise from the same or different underlying mechanisms. In this study, we acclimated six species of *Peromyscus* native to low- or high-altitude environments to both normoxia and hypobaric hypoxia for six weeks. We show that species native to high-altitude have evolved an adaptive blunting of hypoxia-induced increases in red blood cell production (erythropoiesis); in natives of low altitudes, hypoxia-induced erythropoiesis is maladaptive, often resulting in chronic disease or death. Measurements of gene expression reveal that transcriptomic variation is correlated with blunting of the erythropoietic response. Our results suggest that the elimination of maladaptive responses to hypoxia repeatedly evolves in independent high-altitude taxa and thus, is likely to be an important mechanism of local adaptation. The association of transcriptomic variation with phenotypic variation yields new insight into the regulatory mechanisms that drive adaptation of the erythropoietic response.

80-6 VENABLE, CP*; LANGKILDE, TL; Penn State University; *cpv111@psu.edu*

Choice may influence native predator consumption of invasive prey

Invasive species can pose novel threats to native species they encounter or act as novel food resources. Many studies that examine the consumption of invasive prey by native predators are conducted in the absence of native prey options. In order to better understand native predator preference, consumption of invasive prey must be measured in the presence of native prey options. The red imported fire ant, *Solenopsis invicta*, acts as a toxic predator and prey of the eastern fence lizard, *Sceloporus undulatus*. Ants compromise 50% to 80%, adult and juvenile respectively, of fence lizards diets; hence adapting to an invasive venomous ant prey could be vital. Here we test whether fence lizards prefer invasive fire ants or native non-venomous ants and whether this choice changes with experience. We presented lizards with three combinations of ants and recorded their consumption: 1) native non-venomous ants, *Dorymyrmex bureni*, only; 2) venomous invasive fire ants, *S. invicta*, only; and 3) both species presented simultaneously. On first exposure, the lizards killed more native ants than invasive fire ants. Of those ants killed, they consumed the majority of native ants, but crushed and discarded as many fire ants as they consumed. We discuss how the initial preference for native ants changes over time, and how the presence of a venomous species affects the consumption of native prey. Our results suggest that lizards can distinguish between an invasive and native ant species, which may facilitate avoidance or utilization of this novel prey. Lizards appear to kill toxic fire ants to remove them as a predatory threat, but primarily kill native ants for food. We highlight the importance of considering available prey in a landscape when determining consumption of invasive prey.

S7-4 VERBEKE, MC*; PATTISON, S; Institute for Learning Innovatin, ILI; *monae.verbeke@freechoicelearning.org*

Meeting in the Middle: Connecting Your Science Research with the Public's Interests

Identifying strategies that generate increased individual interest may make all the difference in successfully influencing immediate and long-term public engagement with your research science. Interest, the expression of feeling or attraction, is one of the primary precursors to individuals taking action, increasing awareness, or changing behavior. In this session, we will share insights from an on-going study on the communication of scientific research by national park interpreters and its relationship to visitor interests. We are actively exploring how visitor interests are sparked or reinforced during conversations between park interpreters and visitors. Through observations and visitor interviews, we have investigated: (a) behavioral indicators of situational interest, such as curiosity; (b) interpreter's strategies that appear to spark interest, such as visual images; and (c) visitor interpretations of how the interactions sparked or reinforced their own interests. By analyzing the observational data, we are able to suggest drivers of visitor interest, as well as what communication strategies may influence each individual. We believe there are two key factors that are important for influencing the dynamics of visitor interests: communication strategies and research/practitioner partnerships. We will use these finding to suggest ways research can be enhanced by investing in particular communication strategies to increase your research's value and visibility.

P2-51 VERNASCO, BJ; HORTON, BM; RYDER, TB; MOORE, IT*; Virginia Tech, Millersville University, Smithsonian Institute; *itmoore@vt.edu*

Characterizing the androgen response to the acute stress of capture and restraint in free-living male wire-tailed manakins, Pipra filicauda.

Quantifying individual variation in baseline hormone levels in free-living animals is difficult because circulating levels can change due to the acute stress of capture. While the 3-minute rule has been established for measuring baseline glucocorticoids, there is a lack of such a rule for androgens. Further, infrequently checking traps results in variation in how long individuals experience capture stress. Here, we measured the androgen response to two types of potential capture stressors: restraint and being caught in a net. We performed this study on free-living male wire-tailed manakins (Pipra filicauda) in the lowland rainforest of Eastern Ecuador. First, we passively captured males and obtained a blood sample within 3 minutes. We then restrained them for either 15 or 30 minutes before taking a second blood sample. To measure the androgen response to being caught in a net, 10 to 15 nets were set up, filmed using GoPro cameras and checked every 30 minutes. Video footage was then reviewed to determine the amount of time the bird spent in the net before sample collection. Our first study showed that males exhibited a significant decrease in plasma androgen levels following restraint and the major changes in androgens occurred after 15 minutes of restraint. The results of our second study show support for an effect of capture on androgen levels, however, this effect seems to be driven by individuals with the longest net times (i.e., > 40 minutes). This study presents a new technique (filming the net) that can be used to control for the stress-induced changes in androgen levels caused by capture and informs our understanding of how to accurately measure baseline levels of circulating androgens.

P3-158 VERNER, KA; NAUMAN, EA; MAIN, RP*; Purdue University; *rmain@purdue.edu*

Taxonomic Variation in Adaptive Skeletal Plasticity to Mechanical Load: Preliminary Hypotheses.

The skeleton is phenotypically plastic and remodels in response to changes in the mechanical demands placed upon it. Natural selection acts upon the genetic bases for basic skeletal form and the sensitivity of these adaptive mechanisms to load. Here, we take preliminary steps toward comparing functional adaptive plasticity in the limb skeleton of different tetrapod taxa, using the chukar partridge and lab mouse as tractable starting points. We first assessed bone strains in the tibotarsus (TBT) and tibia during treadmill running. Based upon a hind limb loading technique for rodents, we assessed the strains induced in the TBT/tibia during axial compression. Loading studies were conducted in which both taxa received cyclic compression hind limb loading (216 cycles/day, 5 days/wk) to induce strains on the medial bone surface 2.5x the peak treadmill strains. The skeletal response to load was assessed by micro-computed tomography and histomorphometry. The loaded mouse tibia (n=6) was greater in cortical area (+4%) and second moments of area (+6-8 %) than the non-loaded, contralateral tibia. Following loading in the chukar (n=4), the maximum second moment of area was greater in the loaded TBT (+2%) and there were trends for decreased cortical area and increased marrow area in the loaded TBT. The relatively small changes in bone geometry in both taxa did not result in measurable effects by histomorphometry, except that applied load suppressed endosteal bone deposition in the loaded chukar TBTs. The results of these studies preliminarily suggest that different mechanisms may regulate the long bone response to increased mechanical load in these taxa. While the loaded bones of both taxa likely become stiffer in response to load, the murine tibia increases overall bone volume following load, while the chukar TBT becomes stiffer without increasing bone mass.

33-6 VETTER, BJ*; MENSINGER, AF; University of Washington, University of Minnesota Duluth; *bjvetter@uw.edu*

Understanding the Behavior and Auditory Physiology of Flying Carp: an Integrated Approach to Invasive Species Control

Invasive silver carp (*Hypophthalmichthys molitrix*) dominate large regions of the Mississippi River Drainage in North America, outcompete native species, and continue to expand northward, threatening the Laurentian Great Lakes. Silver carp have an unusual jumping strategy that is well documented in news and media outlets but the trigger for jumping remains unclear. Field trials on the Illinois River revealed that silver carp primarily jump behind and away from fast moving (16 - 32 km/hr) boats. The outboard motors (100 - 150 hp motor) emit broadband sound with energy peaks from 0.10 - 2 kHz and 6 - 10 kHz and captive silver carp demonstrated consistent negative phonotaxis (reacting up to 37 times consecutively) to an outboard motor recording. The same sound stimulus (170 dB re 1 µPa SPL_{rms}) also elicited jumping behavior in wild fish when played from a slow moving boat (> 5 km/hr) in the Spoon River near Havana, Illinois. Silver carp are ostariophysans and possess Weberian ossicles that allow for high frequency hearing compared with non-ostariophysans. Auditory evoked potentials indicated that silver carp could detect up to 5 kHz with the lowest threshold at 500 Hz (80.6 ± 3.29 dB re 1 uPa SPL_{rms}). This research implies that broadband sound between 500 Hz - 5 kHz can be used to alter the behavior of silver carp and has implications for deterrent barriers or other uses (e.g. herding fish) that are important to fisheries managers. Research was supported through the University of Minnesota Duluth, the Minnesota Environment and Natural Resources Trust Fund, the U.S. Geological Survey, and the Illinois Natural History Survey.

P3-80 VIDAL, J. M.*; FULLER, R. C.; ANDERSON, P. S.; University of Illinois, Urbana Champaign; *jmvidal2@illinois.edu*

The generation of a repetitive, rapid head-flicking behavior in a killifish and its implications for signaling.

Male *Lucania* killifish court females using a series of repetitive, rapid, head-flicking behaviors where males position themselves beneath females and flick their heads. This behavior is strongly correlated with male mating success and genetic analyses indicate that it is highly heritable. There is some suggestion that the behavior varies between two closely related species (bluefin and rainwater killifish). Yet there is little understanding of (a) how males are stimulating the sensory systems of females and (b) the underlying mechanisms of this behavioral phenotype. *Lucania* killifish possess cranial pores that are a part of the lateral line system, which may be important in detecting this signal. Furthermore, work done in the 1960s suggested that males were generating sounds, but subsequent studies failed to verify this. Here, we present a study that we performed using high speed video to record this repetitive, rapid, head-flicking behavior. Under high speed video capture, the rapid head-flick motion is observed to have a central pivot point within the thoracic region. Rapid motion is detected in both the head and the trunk of body as lateral, periodic movement around this pivot point. Analysis of high speed footage allows for discussion of the rate of head-flicks, amplitude of whole body muscle twitch, frequency of oscillation, and number of oscillations per event. These data help us better understand how males are stimulating females and whether there are important components of this phenotype that differ between two closely related species.

P3-69 VIRGIN, EE*; WEBB, AC; HUDSON, SB; FRENCH, SS; Utah State University; *emilyevirgin@gmail.com*

Inter and intra-clutch variation of egg immunity in Side-blotched lizards (Uta stansburiana)

Neonatal offspring are immunologically naïve and must invest limited resources into costly defenses when encountering pathogens. However, in oviparous species, a female can provide additional immunological protection to her offspring via transfer of antibodies and antimicrobial components to her eggs. Doing so can reduce the energetic cost of mounting an immune response early on in life, when mortality is often at its highest. Although most studies have focused on the effects of maternal investment of immune factors in neonatal offspring, few studies have measured it in a developing egg. In this study, we measured natural variation of innate immune function in the clutches of 15 wild-caught female Side-blotched lizards (49 eggs) via bactericidal, hemolysis, and hemagglutination assays. Preliminary data show inter and intra-clutch variation in egg immunity, suggesting maternal investment varies both between females and even among eggs within the same clutch. The relationship between female and egg immunity, and correlates among immune metrics will also be presented. Maternal investment of resources can drastically affect offspring growth, development, and survival, and thus the results of this study greatly expand our knowledge on dynamics between maternal health, maternal investment, and offspring quality.

S6-2 VITOUSEK, MN*; JOHNSON, MA; MILLER, ET; DOWNS, CJ; MARTIN, LB; HAU, M; HORMONEBASE CONSORTIUM, ; Cornell University, Trinity University, Cornell Lab of Ornithology, Hamilton College, University of South Florida, Max Planck Institute, www.HormoneBase.org; *mnv6@cornell.edu*

Glucocorticoid evolution: a comparative analysis across vertebrates

Glucocorticoids are central regulators of metabolism and the response to stress. Because of the diversity of phenotypic traits that they mediate, glucocorticoid expression could be shaped by many distinct selective pressures. Previous comparative analyses within vertebrate classes suggest that glucocorticoid levels differ according to both environment and life history. Yet fundamental questions about the relative roles of specific selective pressures in shaping glucocorticoid expression in vertebrates remain unanswered. Here we use a newly developed database to test competing hypotheses about the evolution of glucocorticoid levels across vertebrates. This large database, HormoneBase, includes all available measures of plasma glucocorticoids from free-living and un-manipulated vertebrates of both sexes (>2,500 population measures). Using phylogenetically controlled analyses, we use a model selection approach to test the relative roles of energetic buffering, accumulated costs, reproductive value, environmental variability, and stressor mismatch in shaping glucocorticoid expression across vertebrates. This analysis has the potential to elucidate how specific selective pressures may shape these important mediators of phenotype. This approach also illustrates the power and potential of using large data sets, emerging phylogenetic comparative methods, and new analytical frameworks, to test questions of broad relevance to integrative biology.

P2-154 VIZINA, RM*; BERGSMA, GS; University of California, Monterey Bay; *RVizina@csumb.edu*
Comparison of the Ecological Communities that Reside in High Lichen vs. Low Lichen Oak Woodlands
Epibiotic lichens in the genus *Ramalina* are common in California oak woodlands, but the effect of their presence on arthropod communities has not been previously examined. Lichen in oak trees may provide additional habitat or structure in the canopy and may alter light, nutrient, and water availability in the understory, leading to changes in community structure. We compared the arthropod communities living in and among Coast Live Oak trees at the University of California Fort Ord Natural Reserve over spring and summer 2017. Trees were selected based on the amount of lichen cover. Half of the oak trees were within an area with approximately 20% lichen cover, and half within an area of approximately 2% lichen cover. For each tree, we recorded DBH, height, canopy diameter, canopy cover, and understory ground cover. Arthropods were sampled using beat/sweep netting, pitfall traps, brushings, lichen clippings, and litter samples. Arthropod samples were then analyzed in the lab to identify the collected organisms to family. The canopy showed no significant difference in arthropod communities between high lichen and low lichen areas, but under story arthropod communities appeared to differ between high lichen and low lichen areas based on season. These differences may be driven by differences in water availability and phenological changes in the understory vegetation over time.

P2-246 VO, K*; STANKOWICH, T; California State University, Long Beach; *kvokathy@gmail.com*
Effects of Mammalian Aposematic Pattern Variation on Predator Response
Aposematic coloration makes prey defenses easier for predators to learn, recognize, and remember and reduces mistaken attacks. While we know a great deal about predator learning and the evolution of aposematism in avian predators on aposematic invertebrates, mammalian predators and aposematic mammalian prey have been mostly ignored. Coyotes (*Canis latrans*), ubiquitous mammalian predators, overlap in range with and are potential predators of striped skunks (*Mephitis mephitis*), an aposematic prey animal found widely across North America. To determine how contrast intensity and pattern structure influence the speed of avoidance learning in canid predators we are initially conditioning captive coyotes to attack brown benign, baited prey models and subsequently presenting them with noxious spraying prey models that vary in pattern structure and contrast intensity. Differences in the latency to attack or interact with the novel spraying models is compared with respect to the contrast intensity and pattern structure of the model. Past research shows that coyotes can easily learn to avoid attacking black-and-white prey models and can generalize this avoidance to models with greater amounts of white (high contrast) but not to models with greater amounts of black (low or no contrast). Preliminary findings suggest that coyote subjects demonstrate greater latency to attack all black-and-white (maximum contrast) models, regardless of pattern structure, compared to the black-and-gray (minimal contrast) model. If supported by further data, these early results may explain the consistent use of black and white coloration, but large variation in pattern structure, exhibited by skunks in the continental United States.

53-5 VOISINET, MP*; VASQUEZ, MC; ELOWE, C; CROCKER, DE; TOMANEK, L; CA Polytechnic State Univ., SLO, Sonoma State Univ., CA Polytechnic State University, SLO; *mpvoisin@calpoly.edu*
Changes in the proteome of northern elephant seal pups during the postweaning fast
Northern elephant seals (*Mirounga angustirostris*) are subjected to prolonged periods of fasting of up to three months depending on age and gender. In pups, this fast occurs during the postweaning phase, an 8 to 12-week period during which they rely solely on the energy reserves gained during nursing for their caloric requirements and water supply. The postweaning fast is the first of many, and it helps the pup to develop into a diving marine mammal that is capable of foraging at sea. The purpose of this study was to understand the fasting and diving-induced developmental changes of pups during this critical transition from a terrestrial to aquatic lifestyle. To investigate this, we collected skeletal muscle and adipose tissue from pups early and late in the developmental fast. We analyzed the samples with mass-spectrometry-based proteomics using 2D gel electrophoresis. We found significant shifts in metabolic proteins that suggest a decrease in amino acid metabolism and urine production during the postweaning fast, and an increase in alternative metabolic pathways (such as the pentose phosphate pathway) that support cell proliferation. We also found increases in cytoskeletal, skeletal muscle, and oxygen-binding proteins that aid in the development of the diving ability in pups. There were also shifts in the abundance of acute phase proteins that support an increased immune response, possibly due to a higher risk of inflammation from microbial infection. Lastly, there was a shift in antioxidant isoforms that control the production of reactive oxygen species. These results provide key physiological information regarding the developmental pathways of pups throughout ontogeny.

P1-35 VON HAGEL, A.A. *; TSOI, R.; KOLMANN, M.A.; GERRINGER, M.E.; ORR, J.W.; FARINA, S.C.; Univ. of Washington, Wash., Univ. of Washington, Univ. of Washington, Friday Harbor Labs, Univ. of Washington, Friday Harbor Labs, NOAA Alaska Fisheries Science Center, Harvard Univ.; *aavh9@uw.edu*
Use it or lose it: Three ways that snailfishes (Liparidae) reduce their skeleton in the deep sea
Skeletal reduction is a common feature among deep-sea fishes, including snailfishes. However, these fishes must still perform the same functions as their shallow water relatives, thus skeletal reductions may not be uniform. Snailfishes (Liparidae) are found across a large bathymetric range (0-8,200 m), with intertidal ancestors giving rise to speciose deep-sea lineages. We used microcomputed tomography (micro-CT) to estimate average bone mineral density (BMD) and take morphometrics of the jaw, pectoral girdle, and neurocranium. Using correlations of phylogenetic independent contrasts, we found that length of the dentary, pectoral radials, and neurocranium did not vary with collection depth. However, lengths of the premaxilla, angulo-articular, and pectoral girdle decreased with greater depth. Maxillary width decreased with depth, implying more gracile bones. Average BMD of the jaw decreased with increasing depth. The ventral suction disc was also lost multiple times within the deep sea lineage. Our results suggest at least three mechanisms of skeletal reduction: (1) reduction of bone size, (2) reduction of bone density, and (3) loss of skeletal elements. These skeletal reductions may be an adaptation to environmental conditions of high pressures, low temperatures, declining luminosity and sporadic food availability. We conclude that some skeletal elements are maintained at the expense of others as species balance the functional demands in the deep sea.

P3-190 VOSS, KM*; MEHTA, RS; University of California, Santa Cruz; *kmvoss@ucsc.edu*

The Scaling of Eight Arms in Californian Octopuses: Does Arm Length Inform Predator-Prey Interactions?

Octopuses possess many interesting morphological features that enable them to both avoid predation and successfully hunt prey, such as neurally controlled skin camouflage, an ink sac, a raptorial beak with a radula, and eight muscular hydrostat arms with intricate rows of suction cups. Our study focuses on the arms, which are incredibly flexible, and capable of regrowth after catastrophic injury. In other invertebrates, functional specialization has resulted in the differential scaling of morphological traits. Octopuses appear to show little functional specialization in their arms other than the male's hectocotylized arm. However, since the arms in front of the head are usually the first to be exposed in agonistic and defense postures, we hypothesized that the scaling patterns of arm growth would not be isometric. We therefore predicted that the left and right front arms (L1 and R1) would exhibit allometric growth compared to the other arms on each respective side. We measured arm lengths of museum specimens of *Octopus bimaculatus* across a size range, and quantified truncation and regrowth in previously injured arms. Our preliminary data suggest that arm growth is allometric, but the pattern is not bilateral: L1 of uninjured octopuses grew at a faster rate than other arms on the left side, while R1 grew slower than the rest of the arms on the right. Additionally, the left arms incurred over 50% more injuries, and greater proportions of the left arms were truncated. This lateralization was unexpected, as our specimens were collected from a wide geographic area, but may be partially due to a male's need to protect his hectocotylized arm. Future behavioral work is needed to determine whether octopuses favor one side over the other in antipredator displays.

56-2 VOYLES, J*; PEREZ, RG; ROLLINS-SMITH, L; REINHART, L; WOODHAMS, D; RICHARDS-ZAWACKI, C; Univ. of Nevada, Reno, Vanderbilt University, Univ. of Massachusettes, Boston, Vanderbilt University, Univ. of Pittsburgh; *jvoyles@unr.edu*

Understanding Shifts in Amphibian Host Defenses Following Outbreaks of Chytridiomycosis

How do epidemics end? A transition away from the outbreak phase of a disease can occur following the emergence of highly pathogenic infectious agents. Yet the mechanisms that underpin such transitions remain obscure. We have been investigating shifts in disease dynamics in the lethal disease amphibian chytridiomycosis by focusing on host recoveries in the amphibian assemblages of Panama. The fungal pathogen that causes chytridiomycosis, *Batrachochytrium dendrobatidis* (*Bd*), spread through Panama in a wave-like pattern, causing mass mortality events and declines in many amphibian species over a decade ago. However, some host populations that survived initial outbreaks are rebounding despite *Bd* infection. We have found that *Bd* prevalence is now low, but the pathogenicity of *Bd* isolates collected from these populations is still high, causing 100% mortality in naive hosts. This finding suggests that shifts in host resistance to infection may be important for amphibian recoveries. We collected samples of host skin secretions containing anti-*Bd* peptides from multiple species, naive and infected populations, and at numerous time points to test their effectiveness at limiting *Bd* growth. We found that there is wide variation in peptide effectiveness among and within species, as well as in samples collected from numerous time points. We suggest that persisting and recovering populations may have improved innate immune defenses that help protect amphibian hosts against chytridiomycosis.

65-3 WACKER, DW*; WOTUS, C; GREER, AJ; HARTLEY, RS; University of Washington Bothell, Seattle University; *dwacker@uw.edu*

Song sparrows (Melospiza melodia morphna) holding territories under large nocturnal crow roosts show reduced aggression

Songbirds produce song during territorial disputes and distress calls when in mortal danger. Song sparrows (*Melospiza melodia morphna*) respond aggressively to conspecific song playback during both breeding and non-breeding periods. The response of song sparrows to distress call playback is not as well characterized, especially during the non-breeding period. We compared responses of 16 free-living song sparrows to both song and distress call playback on non-breeding territories under large communal crow roosts, which are potential chronic stressors, and on control non-roost territories in western Washington. Birds produced an average of 159 +/- 35 chip calls and 6 +/- 3 songs in response to a 10.5 minute distress call playback, and 36 +/- 17 chip calls and 30 +/- 6 songs in response to an 11 minute song playback. Song sparrows on territories under crow roosts did not show any differences in their responses during or immediately after distress call playback compared to non-roost birds. However, during song playback, song sparrows with territories under crow roosts spent less time within 1m of, made fewer movements towards, and did not as closely approach the playback speaker as birds on non-roost territories. To test the hypothesis that this reduced aggressive response to song is related to chronic stress associated with occupying a roost territory, we are currently measuring baseline and stress-induced plasma glucocorticoid levels.

70-6 WAINWRIGHT, DK*; DI SANTO, V; LAUDER, GV; WANG, J; DONG, H; Harvard University, University of Virginia; *dylanwainwright@fas.harvard.edu*

Tuna finlet function and performance: kinematics, physical models, and fluid dynamics

Tunas and their relatives have a number of behavioral and morphological adaptations to high-performance swimming. One morphological synapomorphy of this group is the presence of finlets - small fins on the dorsal and ventral surfaces of the body between the dorsal and anal fins and the tail. Although finlet kinematics and potential hydrodynamic functions have been studied, we lack an understanding of if and how they alter the hydrodynamics and performance of swimming in these fishes. We use morphological and kinematic data of finlets from Atlantic mackerel and yellowfin tuna to create and compare the performance of simple two-dimensional models of scombrid tails with flexible finlets, rigid finlets, and no finlets. Using these physical models, we quantify performance benefits of passively flexible finlets by measuring self-propelled speed, mechanical efficiency, and force traces during swimming. We also apply computational fluid dynamics to the biological kinematics of finlets in tuna and compare the performance of tuna-like models with and without finlets. Analysis of both physical models and vortex dynamics provides evidence of hydrodynamic functions for finlets during steady swimming.

P1-36 WAINWRIGHT, DK*; LAUDER, GV; Harvard University; *dylanwainwright@fas.harvard.edu*

Mucus matters: the complex and slippery surfaces of fish

Teleost scales differ greatly in morphology and yet we have a poor understanding of the form to function relationship in this system. Researchers have often hypothesized hydrodynamic functions for fish scales, but have largely ignored the mucus and epidermal coatings that cover the surfaces of fish scales in most teleost species. Mucus potentially obscures surface features such as spines and ridges that have been hypothesized to alter flow dynamics over the fish surface. We use gel-based profilometry to examine the surface topography of seven species of fish both with and without mucus and epidermis. Comparisons among surfaces with and without mucus indicate that mucus generally obscures surface features of scales. However, we demonstrate considerable variation in the effect of a mucus coating, and mucus can cause roughness decreases anywhere from 0% to 93%, depending on species and location on the body. Thus, scale morphology alone is not a good predictor of live fish surface topography because diversity also exists in the epidermis and mucus layers. We go further and calculate a k+ parameter that indicates if surface features are likely to change boundary layer flow. We use data from our topography measurements to calculate k+ values for mucus-covered surfaces for all seven species at slow (1 length/second) and fast (3 lengths/second) swimming speeds. These results show that only the surfaces of certain species are likely to change boundary layer flow, providing a theoretical framework for future experimental studies of scales, mucus, and boundary layer flows over fish surfaces.

S2-5 WAKELING, JM*; ROSS, SA; RYAN, D; DOMINGUEZ, S; NIGAM, N; Simon Fraser University, Burnaby, Canada; *wakeling@sfu.ca*

Size, history-dependent and dimensionality effects on muscle contraction

During locomotion the muscles are often used in series of cyclic contractions. Much of what we understand about the performance of cyclic muscle contractions comes from work-loop experiments, but these are typically measured at a fibre-level scale. However, the contractile properties of muscle are affected by the dynamics of muscle size, and so raise questions about how whole-muscle performance can be predicted using data from smaller scales. Modelling studies aid in the understanding of muscle performance. Comparative studies commonly use a Hill-type muscle modeling framework that is derived from steady contractions and so may not account for unsteady and history-dependent effects that occur with cyclical contractions. Furthermore, Hill-type models typically do not include the dimensionality or base properties of the muscle, and both of these have been shown to influence force development. We developed a modeling framework to drive an oscillating inertial load using a Hill-type muscle actuator. The muscle was modified to include history-dependent effects, internal mass, and 3D geometry with base-material constraints, and was tested at different scales from single-fibre to whole muscle. The muscle was driven by a varying activation, and resulted in cyclic work-loops from which the force and power output could be determined. We report on the relative contributions of these muscle parameters to the overall contractile performance during cyclic contractions.

81-6 WALDROP, LD*; HE, Y; MILLER, LA; New Mexico Tech, Univ. of North Carolina at Chapel Hill; *lindsay.waldrop@nmt.edu*

Using uncertainty analysis to explore the effects of variation on a functional system

Biologists have long understood the importance of variation in evolution. Variation provides the raw materials on which natural selection acts, leading to potentially important differences in functional performance. Varying parameters in complex, functional systems can lead to unpredictable effects on the performance of such systems, displaying synergy (effects of more than sum of the changes alone) or many-to-one mapping/mechanical equivalence (many parameter combinations result in similar performance). Understanding how simultaneous variation in parameters impacts the performance of a system is key to understanding how natural selection has shaped these functional systems over time. In this study, we take a simplified version of a very complex functional system (circulatory flow driven by a peristaltic heart) and subject it to uncertainty analysis, a set of mathematical techniques that assess the uncertainty in complex, physical systems. We use uncertainty quantification and sensitivity analysis through generalized polynomial chaos expansion to simultaneously assess the impact of variation in three main parameters of this model. Through this analysis, we quickly and efficiently distinguish sensitive parameters (compression ratio of the tube) over relatively insensitive parameters (Womersley number, compression frequency) through the use of Sobol indices. We also extend the interpretation of the sensitivity analysis to make predictions about the variance of these parameters in living animals: sensitive parameters being highly conserved versus insensitive parameters being free to diversify.

38-7 WALKER, J*; KANO, F; TAYLOR, G; BIRO, D; University of Oxford; *jameswalker300@gmail.com*

Gaze strategy during flight in homing pigeons

Homing pigeons (*Columba livia*) have a large panoramic visual field extending over 340 degrees. Directing and stabilising their visual system during flight is essential for flight control, extracting important navigational cues from the environment and anti-predator vigilance. However, pigeons have only a limited range of eye movement during flight and instead rely largely on their flexible necks to stabilise their gaze. To investigate the gaze strategy adopted during free flight, pigeons were fitted with a head-mounted inertial measurement unit and GPS device and released from sites within their familiar area. This setup allowed us to characterise head direction and saccadic head movement in relation to their track over the ground. In this talk I will present the findings of an analysis of gaze direction in relation to navigational features of the environment.

73-3 WALKER, S M*; CHABOKDAST, A; University of Leeds, University of Oxford; *s.walker1@leeds.ac.uk*
Amplification and transmission of muscle strains in the dipteran flight motor
In almost all insects the wings are powered through two antagonistic groups of flight muscles. These indirect power muscles are so called because instead of inserting directly onto the wing, they instead attach onto the thorax. They produce tiny, linear strains that cause the thorax to deform in such a way as to amplify and transform this movement into the much larger, angular motion of the wing via the complex wing hinge. We currently have a poor understanding of how this intricate mechanism works. This is in large part due to the extraordinary difficulty in measuring micrometre-scale muscle movements *in vivo* at frequencies in excess of 100 Hz. Here, we used synchrotron-based, time-resolved microtomography to visualise the three-dimensional movement of the flight motor of blowflies (*Calliphora vicina*) during tethered flight. We then tracked the movement of power muscle end points, flexure regions on the thorax, and the wing hinge sclerites to create a kinematic model of the flight motor. The results show that the insect thorax can be modelled as a rigid four bar linkage, which captures the movement of the thorax and muscle strains. Despite attaching to the same linkages, the slight differences in orientation of the two sets of power muscles results in antagonistic effects on the linkage model. The four bar linkage allows the linear strains produced by the muscles to be converted into an angular motion, but with only a small amount of amplification. Instead, the movements are transmitted to the wing hinge via the scutellar lever and it is there that the angular motion is mostly amplified. However, the wingtip amplitude is still considerably larger than that of the wing hinge, indicating that much of the wing motion is caused by passive aeroelastic effects.

P2-28 WALTERS, LJ*; GIBBS, V; University of Central Florida; *linda.walters@ucf.edu*
Oyster Storytelling Yoga: Engaging Children and Adults to Care about Oyster Reefs and Estuaries
Yoga has traditionally been practiced for physical, mental and spiritual well-being. Here, we describe our new oyster storytelling yoga efforts to help children and adults learn about estuarine ecology, all while being engaged and physically active. Our goal is to share with children the importance and challenges faced by oysters and oyster reefs through the principles of good storytelling, with the students participating in large muscle movement and calming activities with yoga-style affirmations. Our strategy is to have participants begin their journey onshore with breathing (mosquito breath) and stretching (calm water and shell midden) poses, and then travel by boat (traditional yoga: boat pose) to an oyster reef after traversing the crests and troughs of waves (traditional yoga: cat and cow poses), and then meet some of the amazing biodiversity on and around the oyster reefs (modified yoga poses: crabs, wading birds, dolphin, etc.). Our planned deliverable is a set of large, two-sided cards with a photograph of each pose facing the audience and the storytelling text plus step-by-step instructions for poses on the side facing the educator. Versions have been tested in the field with K-12 educators and community members ranging in age from 2 - 82. We consider this to be a novel, exciting way to share STEM content on estuaries and biodiversity with children and adults. Funding for this project was provided by NSF CNH grant #1617374.

P1-202 WALTON, MD*; JOST, JA; Bradley University; *mwalton@mail.bradley.edu*
Investigating the acute impacts of multiple environmental stressors on zebra mussel physiology
Given that invertebrates can be commercially important, indicators of ecosystem health and climate change, or invasive, their physiology is of interest. As conformers, invertebrates experience physiological changes as temperature and dissolved oxygen (DO) levels, vary. Increased water temperatures due to climate change and decreased DO levels due to nutrient runoff are altering these habitats. Even though stressors often co-occur, few studies have investigated their combined effect. The invasive zebra mussel was used as a model species for examining the effects of heat and hypoxia, alone, and in combination. Mussels were collected in central IL and exposed to heat, hypoxia, both, or neither for 6 hours. Three cellular stress markers were evaluated: heat shock protein 70 (HSP70) as an indicator of protein denaturation, phosphorylated AMP-activated protein kinase (active AMPK) as a measure of metabolic balance, and total AMPK levels as a measure of the pool of available molecules. Results show active AMPK levels increased over time but then returned to baseline levels with extended exposure to either heat or hypoxia alone. However, active AMPK increased and remained elevated over time when these stressors co-occurred. Total AMPK and HSP70 levels increased over time in response to either heat and hypoxia, but remained at baseline levels in response to heat and hypoxia in combination. One possible explanation is that the cumulative effects of heat and hypoxia are too energetically taxing for protein synthesis. If so, increased levels of active AMPK could be explained by phosphorylation from within an existing pool of molecules. Therefore, these results suggest that there is a synergistic effect, where exposure to both heat and hypoxia is more stressful that the effect of either in isolation.

P3-134 WANAMAKER, SM*; CRESPI, EJ; Washington State University, Washington State University ; *sarah.wanamaker@wsu.edu*
Behavior mitigates the effects of increased temperature in a plethodontid salamander
The physiology and behavior of amphibians is inextricably linked to ambient temperature. Thermal differences are predicted to mediate plastic responses in growth, developmental rates, cell size, body size, and ultimately life history characteristics. Global warming may affect many biological processes, yet the consequences of global warming on proximate physiological responses are poorly studied. Our experimental design aims to determine the consequences of global warming by measuring several characteristics related to survival and reproduction in amphibians. We hypothesized that in higher temperatures, salamanders will allocate more energy to metabolism and basic cellular processes while maintaining fewer energy stores for reproduction. If this hypothesis is supported, rising global temperatures may have negative implications for reproductive success of ectotherms. We collected gravid *Desmognathus ocoee* females and maintained them at two different temperature regimes (16°C and 25°C, based on average low and high temperatures during reproductive season in their home range) throughout their yearly ovarian cycle. Measurements indicative of resource allocation (growth, lipid deposition, egg number and size) were recorded to monitor physiological differences between the treatment groups. Our results indicate no difference in somatic or reproductive allocation between temperature treatments. Rather, differences in metabolic demands were mitigated through feeding rate. Although dependent on food availability, such behavioral plasticity indicates the ocoee salamander has some capacity to cope with increased temperatures with little or no fitness costs.

P2-209 WANG, W-S; SHIH, M-C; CHI, K-J*; National Chung-Hsing University, Taiwan; *kjchi@phys.nchu.edu.tw*

Dynamics and Ecological Consequences of Violent Sperm Discharge in Liverworts

Dispersal of diaspores plays a critical role in plant ecology and evolution. For the microscopic pollen or spore to break through the boundary layer, specialized discharging systems have evolved. In this study, we analyzed the high speed videos of sperm discharge in liverwort *Conocephalum conicum* by fitting the tracked trajectory with fluid dynamic models, and further took kinematic and climate data to estimate the dispersal range. Our results showed that a simple discharge could make sperms shoot at initial velocity of 8.77±3.31 m/s through an opening of 5 µm in width, atomized to droplets of 20 µm in diameter, and reach an average height of 3.1 cm, which was greater than what the ballistics model would predict for a single particle. Constant drag model fit the trajectory well, but underestimated the particle size by 1-2 orders of magnitude, suggesting its aerodynamic efficiency. During the mature season of antheridial disks, the sperms could break through the boundary layer generated by light air or light breeze at 2 m downstream. Light breeze could transport the sperms for over 6 m horizontally, and the dispersal range is affected by the variance of particle radius, discharging height, and wind speed. Compared to the classic discharging plants *Sphagnum*, *C. conicum* takes a different strategy by atomizing sperm fluids through a smaller opening, and prolonging discharge duration for the frontal sperm droplets to accelerate the surrounding air, which consequently makes the succeeding ones reach a greater height. This first study on discharge of sperm fluid particles in plants provides new insights into their dispersal mechanics, as well as bio-inspired spray design for various needs.

94-4 WANG, AZ*; HUSAK, JF; University of St. Thomas, MN; *wang0093@stthomas.edu*

Effects of Specialized Exercise Training on Innate and Adaptive Components of the Immune System.

The immune system is segmented into two general parts that defend against foreign pathogens: innate and acquired. Innate immunity is made of rapid, non-specified germ line-encoded responses that act as the first line of defense against pathogens. Acquired responses are usually slower and more specific responses that need to be activated to serve as a secondary line of defense. Both elements are energetically costly and may conflict with energy required for physical performance, resulting in a potential trade-off between the two systems. Though exercise has been shown to have a direct effect on the immune system, few studies have been able to tease apart the specific effects exercise has on different components of immunity. Different forms of exercise also lead to different energy expenditures; sprint performance is largely anaerobic and depends on muscle size, while endurance performance is aerobic and depends on efficient oxygen delivery to tissues. We predicted that endurance-trained lizards would have increased cellular immunity when compared to the lizards that were sprint trained due to the increased allocation of energy to increased muscle mass, leading to a lack of energetic resources available to devote to immunity. We measured immunocompetence in 3 treatments of lizards: endurance trained, sprint trained, and not trained. We then measured the swelling response to phytohemagglutinin (cell-mediated), antigenic response to sheep red blood cells (humoral), bacterial killing ability (innate), and wound healing (integrated). Results showed significant differences in immune function between treatment groups, as well as differential trade-offs among the different components of the immune system.

P3-247 WANG, X; KONG, L*; CHEN, J; MATSUKUMA, A; LI, Q; Key Laboratory of Mariculture, Ministry of Education, Ocean University of China, Qingdao, China, Institute of geology and paleontology, Linyi University, Linyi, China; *klfaly@ouc.edu.cn*

Integrative Taxonomy of Meretrix Species (Bivalvia: Veneridae) from the Northwestern Pacific

The bivalve genus *Meretrix* Lamarck, 1799, broadly distributed in the Northwestern Pacific, contains several important marine economic species in East Asia. However, taxonomy of *Meretrix* species is controversial because of similar shell morphology and changeful color patterns. With the aim of the exploring taxonomy and biogeography of *Meretrix* species from the Northwestern Pacific, we analyzed 305 samples collected from 29 locations with an integrative analysis combining morphological and molecular data (COI and ITS-1). The results revealed that Genus *Meretrix* includes six species at least: *M. petechialis* (Lamarck, 1818), *Meretrix meretrix* (Linnaeus, 1758) [= *M. lusoria* (Röding, 1798) of authors], *M. lamarckii* (Deshayes, 1853), *Meretrix castanea* (Lamarck, 1818) [= *M. meretrix* (Linnaeus, 1758) of authors], *M. lyrata* (G. B. Sowerby II, 1851) and *M. planisulcata* (G. B. Sowerby II, 1854). In contrast to previous studies, we proposed that *M. petechialis* and *M. meretrix* should be recognized as different species. In addition, deep divergences found in the *M. petechialis* and *M. lamarckii* suggest the occurrence of potential cryptic species.

14-4 WARBURTON, EM*; KHOKHLOVA, IS; DLUGOSZ, EM; VAN DER MESCHT, L; KRASNOV, BR; Ben Gurion University of the Negev, University of Tennessee; *warburte@post.bgu.ac.il*

Effects of Parasitism on Host Reproductive Investment in a Rodent—Flea System: Host Litter Size Matters

Individuals may alter their reproductive investment depending on the type of environment they encounter. Females experiencing stressful conditions might opt to alter sex ratios of litters or invest more into current rather than future reproduction. In the context of parasitism, these effects could manifest as parasitized mothers producing more female offspring, as in the Trivers-Willard Hypothesis, or producing offspring that reach maturity quickly. Our goal was to determine if infestation by fleas *Xenopsylla ramesis* and *Parapulex chephrenis* altered sex ratio, number of offspring, or litter quality in two rodent species: *Meriones crassus* and *Acomys caharinus*. Further, flea infestations included characteristic fleas and non-characteristic fleas to determine if number and type of fleas significantly altered host reproductive investment. We found no effect of infestation on sex ratio for either rodent species and no effect of infestation on litter mass, litter size, or pup mass gain in *A. caharinus*. However, treatment did have an effect on litter mass in *M. crassus*. Further, a significant interaction between treatment and litter size on pup mass gain in *M. crassus* indicated that small, parasitized litters gain the most mass. These results suggest that, at least in *M. crassus*, infested mothers produce offspring that mature more quickly but do not alter sex ratio of their litters in response to infestation. Thus, mothers may invest more in current reproduction when subjected to the stresses of parasitism.

14-6 WARNE, RW*; CRAVENS, ZM; PARROTT, JC; KIRSCHMAN, LJ; BOYLES, JG; Southern Illinois University, Carbondale, Univ. of Alaska, Anchorage; *rwarne@siu.edu*

Critical disease windows among animals with complex life histories may underlie epizootics in a changing world

Many organisms experience periods, either seasonally or ontogenetically, of increased vulnerability to disease. We argue here that an unexpectedly large number of emerging epizootics are characterized by an overarching commonality: the host species exhibits complex life histories or life cycles. Among wildlife, examples include White-nose Syndrome (WNS) in bats, sea-star wasting disease (SSWD), coral epizootics, and diverse virulent pathogens afflicting amphibians. For example, WNS is a fungal disease that cycles seasonally in bats, in which hibernation behavior and immunosuppression by the hosts are primary factors determining vulnerability to infection. Similarly, chytridiomycosis and ranavirosis epizootics in amphibians occur around metamorphosis and are exacerbated by ontogenetic shifts in immunity and behavior. These similarities suggest that critical disease windows—periods of increased vulnerability—are shaped by shifts in host susceptibility and exposure to pathogens. Furthermore, environmental change may alter the scale and scope of epizootics in species with complex life histories/cycles by altering windows of disease vulnerability and thus forcing changes in host susceptibility and/or pathogen exposure. Growing evidence suggests that climate change, in particular, can exacerbate many wildlife epizootics through alteration of timing of important events over the life of the host and pathogen. We present a framework to conceptualize these interacting factors. We then explore how this framework may increase our understanding of how environmental change interacts with complex life histories and physiological states to predict epizootic outcomes.

P3-228 WARNER, DA*; PEARSON, PR; Auburn University; *daw0036@auburn.edu*

Natural selection on thermal reaction norms of lizard embryos

Theory predicts that natural selection will favor plasticity in spatially or temporally heterogeneous environments that vary in predictable ways. Like most traits, the potential for plasticity to evolve depends on the degree of heritability and strength of selection. To gain insight into evolution of plasticity, we assessed among-family variation in developmental plasticity for a variety of phenotypes in the brown anole (*Anolis sagrei*), and then evaluated the strength of selection on family-level reaction norms. Eggs from wild-caught females were incubated under thermal environments that mimicked temperature regimes characteristic of the early vs late reproductive season. Offspring were uniquely marked, measured for their size and locomotor performance, and then released onto an island near the collection site of their mothers. Recapture efforts were performed before and after the first winter to quantify offspring survival and natural selection on phenotypes, as well as on family-level developmental plasticity. Incubation duration was significantly shortened by late-season temperatures, and this pattern did not differ among family groups. For morphological and performance traits, however, late season thermal conditions generally produced larger and faster offspring than early season regimes, but the strength and direction of the effects varied substantially among family groups. This family-level variation in reaction norms suggest that plasticity observed here might have a genetic basis. In addition, this variation in reaction norms provides an opportunity for selection to operate on plasticity. Next, we will quantify the strength and form of selection on reaction norms to better understand how embryo responses to developmental environments are shaped by selection.

77-4 WARRINER, TR*; SEMENIUK, CAD; PITCHER, TE; LOVE, OP; GLIER, Univ. of Windsor, Canada, GLIER, Univ. of Windsor, Windsor, Canada, Biological Sciences, Univ. of Windsor, Windsor, Canada; *warrinet@uwindsor.ca*

Adaptive stress: maternal stress as a modulator of salmon offspring survival and performance under climate change

Climate change is a major driver of elevated water temperatures globally, altering temperature regimes, which can substantially impact aquatic life particularly for oviparous fish species whose early development is temperature-dependent. When mothers encounter stressors such as elevated temperatures during follicular recruitment (maternal stress), resulting offspring often have altered phenotypes. Although these effects were previously often considered negative, recent studies suggest that this maternal stress signal may prepare offspring if they also face a similarly stressful environment (environmental match). We applied the environmental match hypothesis to investigate whether a maternal stress signal can prepare offspring for a stressful environment under climate change. Specifically, we exposed Lake Ontario Chinook salmon (*Oncorhynchus tshawytscha*) eggs to a biologically relevant maternal stress signal (1000ng/mL cortisol or control). We then split these groups and incubated them at temperatures indicative of current and future climate conditions (3°C higher). We examined offspring survival in early rearing environments, and experimentally tested the ability of the offspring to metabolically cope with chronic thermal stress by exposing the offspring to temperature spikes over 3 consecutive days. We assessed their metabolic response to extreme variation in temperature through their plasma cortisol, glucose and lactate levels. By examining an ecologically and commercially important fish within the environmentally relevant context of climate change our results should facilitate predictions of how fish populations may cope with the rapid increase in water temperatures under projected climate scenarios.

S7-2 WATKINS, TB; National Park Service; *tim_watkins@nps.gov*

Science Outreach and Engagement in National Parks

The United States and its territories contain over 400 national parks and other protected areas managed by the National Park Service (NPS). Collectively, these sites attract over 300 million visits per year which makes the NPS one of the largest informal education institutions in the country. That education can and does include science. Because the NPS supports and facilitates scientific research in parks, the national park system provides boundless opportunity for scientists to engage diverse audiences in learning, exploring, and even conducting science. Those opportunities are best pursued through collaborations between researchers and the parks' interpretive and education staff and with non-NPS education partners who work in parks. Among other activities, scientists in these collaborations are conducting citizen science projects, contributing to teacher education workshops, helping interpreters develop new programs and visitor center displays, presenting research results at annual in-park science symposia, and appearing in science videos posted on park websites and social media. This presentation explores lessons the NPS and its partners have learned about effective practices and impact of scientists' involvement in public outreach and engagement. It also identifies what still needs to be learned. Examples from parks will illustrate the diverse ways in which scientists, park staff, and partners customize outreach opportunities according to their different strengths, interests, and capacity. The presentation aims to provoke interest and new ideas among session participants for making science part of the park visitor's experience.

131-5 WATSON, CM*; BURGGREN, WW; WOLINSKI, CJ; COX, CL; Midwestern State University, University of North Texas, Georgia Southern University; *charles.watson@mwsu.edu*

Variation and evolutionary dynamics of squamate metabolism.

A complex set of relationships exists between animal body size, body temperature, and metabolism. Metabolic rates (VO_2) at different temperatures and associated temperature sensitivity (Q_{10}) are well documented among squamate reptiles, providing an opportunity to study how metabolism, as a physiological trait, evolves over time and across taxa. Using a dataset of 300+ species, we investigated how metabolism scales with temperature and body size in a phylogenetic context. A significant phylogenetic signal across or within lower taxonomic suggests that metabolism is a conserved trait, while no signal and high variation indicates metabolic plasticity. These data provide an updated and comprehensive review of squamate metabolic rate, allometric relationships of metabolism to temperature and body size, and addresses the phylogenetic constrains on metabolism both across and among taxonomic groups.

P1-76 WATTS, E. F.*; MILLER, T. T.; MEEKS, E. J.; AMPOSTA, J. P.; FOLTZ, S. L.; MCGLOTHLIN, J. W.; Ohio University, Virginia Tech; *efw24@vt.edu*

Environmental Factors Effect Aggression in Brown Anoles

Male brown anoles (*Anolis sagrei*) are a lizard native to Cuba and the Bahamas which defend small territories from other males. Aggressive displays include behaviors such as head bobs, push-ups, and dewlap flashes. These aggressive displays, in addition to direct attacks, are attempts by the male lizards to secure and defend their territories. An earlier study in our lab showed population differences in aggression of wild-caught adult male brown anoles from four Bahamian islands: Exuma, Eluthra, San Salvador, and North Andros. This study extends that work to lab-reared male offspring of those same four populations to determine whether population differences in aggression persist despite a common-garden rearing environment. A pilot study using size-paired offspring from only Exuma and Eluthera populations suggested that developmental environment and immediate circumstances may have a stronger influence on aggression than parentage. Males of at least 15 months of age were size-matched with another member of their population, visually isolated from other lizards for one week, and then tested. The paired lizards were tethered and placed in a novel enclosure where they could see each other for 30 minutes. Video recordings of these encounters scored based on aggressive displays. Focal males were also tested individually, using a mirror as a stimulus, to determine the impact that the presence of another lizard may have on aggressive behavior. Each lizard was tested twice in both manners to measure repeatability of aggression in both settings. These data indicate that aggression in male brown anoles is influenced by both the environment in which they are raised as well as their immediate environment rather than by parentage.

P3-201 WATTS, RC*; KING, RW; BAKER, JA; FOSTER, SA; Clark University; *rwatts@clarku.edu*

Possible Mutation Accumulation in Unexpressed Plastic Phenotypes: Insights from Threespine Stickleback

Phenotypic plasticity, the capacity of a genotype to produce more than one phenotype in response to differences in environment, has the potential to influence subsequent evolution. One way in which this can occur is that a shift from a variable to a stable environment, can cause some genetically-based aspects of the phenotype, ordinarily expressed in response to alternative environments, to be unexpressed for extended periods. Under these circumstances, mutations can accumulate in conditionally-expressed genes that are not expressed in the new environment. This can have several outcomes including degradation of gene function, greater individual variation in expression and the expression of novel phenotypes. Here we evaluate these alternatives in a population of threespine stickleback fish, *Gasterosteus aculeatus*, which is undergoing rapid plastic re-emergence of an ancestral foraging mode as a consequence of anthropogenic productivity increase in Lynne Lake, Alaska. As productivity increases, the limnetic, plankton-feeding stickleback native to the lake are living longer, growing faster and shifting to the benthic, ancestral foraging. Large body sizes and benthic foraging have likely been absent from this population since post-glacial colonization. We present data from this population spanning 20 years (1992-2012), the earliest data from the period before this phenotypic transition was initiated. We further present data from two historically benthic populations and ask whether the trophic structures and head shape of benthic adults in Lynne Lake are more variable than are those from historically benthic populations as might be expected under the mutation accumulation hypothesis.

2-6 WEAVER, L. N.*; WHITNEY , M. R.; WILSON, G. P.; University of Washington; *lukeweav@uw.edu*

Osteohistology of Multituberculate Femora from Northeastern Montana Suggests Variation in Growth Rate Near the K-Pg Boundary

The Multituberculata were the most abundant and species-rich mammalian clade in many Late Cretaceous terrestrial ecosystems; however, their fossil record consists largely of isolated teeth and jaws, which makes it difficult to understand life history traits of these extinct animals. Osteohistological proxies can provide insights into the growth strategies of fossil taxa; therefore, in order to develop a more comprehensive view of multituberculate biology, we report on the osteohistology of five multituberculate specimens from northeastern Montana. All specimens are isolated proximal femora, which are assigned to two separate morphotypes: Mu1, represented by one specimen from the uppermost Cretaceous Hell Creek Formation, one from the lowermost Paleogene Tullock Formation, and two from the Bug Creek Anthills locality (which yields a mixed assemblage of Cretaceous and Paleogene taxa) and Mu2, represented by one Hell Creek specimen. The bone microstructure is consistent across all Mu1 specimens and suggests a period of rapid bone deposition early in ontogeny followed by slower bone deposition, whereas the Mu2 bone microstructure suggests a continued slow rate of bone deposition. Although our sample is small, these preliminary data suggest that Mu1 taxa had a fast rate of growth early in ontogeny which later slowed, and that Mu2 taxa had a consistently slow rate of growth. Mu1 is found across the Cretaceous-Paleogene (K-Pg) boundary, whereas Mu2 is only found in the Cretaceous, which may suggest a selective advantage for fast growing taxa during the K-Pg mass extinction. Further sampling is in progress to better understand the role of growth rates in the survival of multituberculates across the K-Pg boundary.

P1-300 WEAVER, JC; Wyss Institute, Harvard University; *james.weaver@wyss.harvard.edu*

New Scanning Electron Microscopy Imaging Techniques for the Large-Scale High-Throughput Characterization of Hierarchical Biological Materials and Synthetic Constructs

There has been significant progress in recent years aimed at pushing the spatial resolution limit of scanning electron microscopes. Many of these endeavors have been driven by advances in the field of nanotechnology and the need to investigate the morphological features of sub-micron size materials. While scanning electron microscopy is indeed a powerful tool for investigating objects at length-scales that are prohibitive using standard optical microscopy techniques, SEMs are also extremely useful in characterizing the micro- and macro-scale architectures of transparent, highly reflective, or morphologically complex materials. In this present study, three scanning-electron microscopy imaging techniques (wide-field, polychromatic, and stereo) will be introduced and applied to the imaging of a wide range of hierarchical biological and synthetic structural materials across length scales covering more than 5 orders of magnitude (less than 10 μm to greater than 10 cm).

102-3 WEBB, AC*; KNAPP, C; IVERSON, J; DENARDO, D; FRENCH, S; Utah State University, John G. Shedd Aquarium, Earlham College, Arizona State University; *alisoncarey4@gmail.com*

The effects of tourism and food provisioning on the physiology of Exuma Rock Iguanas (Cyclura cychlura)

Tourism in the Bahamas has led to near daily interactions with humans and provisioning of atypical food items for some populations of Cyclura iguanas. Long term studies of these populations have found them to exhibit unnaturally high densities on feeding beaches, higher endoparasitic infections, altered dietary nutrition, and to have decreased survival probability compared to populations not being visited by tourist groups. In this study, we expand on previous work to assess the impacts of dietary changes and anthropogenic activity on the physiology of iguana populations experiencing different degrees of tourism activity. We sampled both male and female iguanas in post-breeding condition from 6 sites. The sites were categorized as experiencing high, moderate, or low tourist activity based on the amount of tourist which visit each site. Iguanas from high tourism populations have increased triglycerides and glucose, elevated activation of the immune system, increased reactive oxygen metabolites, and decreased circulating corticosterone compared to populations experiencing low or moderate tourism and food supplementation. Tourism in the Caribbean is likely to continue and understanding physiological mechanisms mediating survival could allow us to better influence conservation policy and understand the changes driven by anthropogenic forces.

S5-11 WEBB, B*; LOVELESS, J; LAGOGIANNIS, K; WYSTRACH, A; University of Edinburgh; *B.Webb@ed.ac.uk*

Modelling sensory feedback and locomotor dynamics in Drosophila larvae

The Drosophila larva is an important model system for understanding the interaction of neural circuits and body mechanics in directed locomotion. Its behaviour is often described as alternating between straight peristaltic crawling (runs) and lateral bending to reorient (turns), either for random exploration or to move up or down a sensory gradient (taxis) by making appropriate 'decisions' when to switch. Our analysis of larval motion suggests that there is actually a continuous underlying lateral oscillation and we show that a simple agent model that modulates its amplitude of oscillation according to the change in sensory input can reproduce a surprising range of the characteristics of taxis in larvae; importantly this depends on the closed-loop shaping of the sensory input by motion. To better understand the control of motion we have developed a mathematical model of larval segmental mechanics, and show that (in the absence of damping and driving) the mechanics of the body produces axial travelling waves, lateral oscillations, and unpredictable, chaotic deformations. Adding a simple reflexive neuromuscular circuit to this model to counter friction gives rise to forward and backward peristalsis and turning, even though the nervous system neither senses nor drives bending motions. Finally, by adding an additional reflex to enhance bending in response to sensory input, we can produce directed taxis that closely resembles the observed behaviour of larvae in a sensory gradient.

88-4 WEBB, SJ*; TAYLOR, JRA; Scripps Institution of Oceanography, UCSD; *s3webb@ucsd.edu*

Settling to the Bottom: Importance of Temperature and Calcification for Adult Phases of Tuna Crabs

Tuna crabs (*Pleuroncodes planipes*) are becoming common in southern California, north of their historical center in southern Baja, Mexico. This is in concert with warm water temperatures and transport associated with El Niño and suggests warm optimal temperatures and potentially a range shift/expansion. Tuna crabs are unique because adults go through a ‘pelagic' phase, during which they migrate between the benthos and water column, until they reach a certain size, and become fully benthic. These different phases expose animals to variable temperatures and other physical/chemical conditions that may involve modifications of the exoskeleton, yet little is known about these aspects of their biology. I tested the hypotheses that (1) warmer water is optimal for tuna crab growth and (2) the exoskeleton undergoes structural and compositional changes associated with the shift from pelagic to benthic phases. Pelagic animals were maintained in two temperature treatments (cool: 12°C and warm: 18°C) for two molt cycles. Molting was monitored and growth was measured as percent increase in carapace length. Tuna crabs in the warm treatment had a higher molt frequency, but the same molt increment as those in the cool treatment, suggesting that they reach benthic phase size sooner. Benthic and pelagic animals were also collected via trawl and their exoskeleton structure and composition were compared using SEM and EDX. Preliminary analysis reveals that benthic animals have a similar, but more heavily calcified exoskeleton than pelagic animals, suggesting that increased mineralization is important for this transition. This study addresses key aspects underlying a potential tuna crab range expansion or shift, as growth and calcification influence benthic settlement and both are sensitive to oceanographic conditions.

P1-52 WEBER, HE*; WINTERS, GC; BOBKOVA, Y; BOSTWICK, C; KOHN, AB; MOROZ, LL; Transylvania Univ., Neurosci., Univ. of Florida Whitney Lab; *hannahweber20@gmail.com*

Uncovering the Secret Secretory Molecules of the Octopus bimaculoides Learning and Memory Circuit

Octopuses exhibit behavioral flexibility and demonstrate a remarkable ability to learn and remember, which is the result of a centralized nervous system containing about 500 million neurons. Cephalopod nervous system centralization is an example of convergent evolution, with parallel centralization events occurring multiple times throughout evolutionary history. The learning and memory circuit present in *Octopus* is located in the vertical lobe and contains three different categories of neurons: superior frontal lobe cells, amacrine interneurons, and large efferent neurons. For this project, we examined secretory molecules (neuropeptides and classical neurotransmitters) present in the memory forming circuitry of *Octopus* and localized them in *Octopus* neural tissue. Using standard molecular cloning techniques and *in situ* hybridization, we effectively identified and localized three new neuropeptide molecules in vertical lobe circuit cells, one of which labels presynaptic superior frontal lobe cells while the other two label large efferent neurons. Additionally, we identified two of the first markers for glial-like cells in *Octopus*. We also cloned Nitric Oxide Synthase for the first time in *Octopus* and identified both nitric oxide and dopamine (via Aromatic-L-Amino Acid Decarboxylase) as potential vertical lobe neurotransmitters. Considering these findings together, the independent evolution of *Octopus* brains appears to have employed a unique combination of both neuropeptides and classical neurotransmitters, broadening our understanding of convergent evolution in distant phyla as well as revealing new questions to address in the future.

122-7 WEHRLE, BA*; TRAVERNE, M; HERREL, A; KRAJNOVIC, M; TADIC, Z; GERMAN, DP; Univ. of California, Irvine, CNRS-MNHN, Univ. of Zagreb; *bwehrle@uci.edu*

Interplay of gut length, diet, and ecology in lacertid lizards

A transplanted population of Italian Wall Lizards (*Podarcis sicula*) from an island in Croatia has become omnivorous and morphologically distinct from its source population in ~30 generations, making it a compelling example of rapid evolution. Vertebrates that eat plants often have longer guts to accommodate diets with low nutrient densities and recalcitrant components, such as fiber. However, this new *P. sicula* population does not have longer gut lengths than its source population. Still, sex differences in gut length were only apparent in the new population. Are these populations too recently diverged to find differences in gut length? Do females usually have longer guts? To more broadly understand the ecological drivers of gut length in natural systems, we surveyed other *P. sicula* populations, and their sister species, *Podarcis melisellensis.* We expect lizards that eat more plants will have longer guts, and that sex effects increase concomitantly with herbivory. We sampled *P. sicula* from 5 islands, *P. melisellensis* from 8 islands, and one mainland population of each species. From each site, we analyzed lizard stomach contents to determine ingested diet and measured gut lengths. Dietary analyses, including taxa and component consumed, are still underway, but preliminary data reveal only *P. sicula* populations consumed considerable proportions of plants. Intestine length will be analyzed in the context of diet data. Females had longer guts in half the populations, regardless of species. *P. melisellensis* generally had shorter guts than *P. sicula*, and their gut lengths differed among 1/3 of populations. However, *P. sicula* gut length only differed between two populations. This suggests *P. sicula* may have canalized longer gut lengths, giving them an advantage to make the transition to plant based diets.

P3-255 WEIGAND, NM*; TONRA, CM; WAGNER, RD; POPESCU, VD; Ohio University, Ohio State University; *nw178500@ohio.edu*

Evaluating potential effects of proximity to roadways in a road-naïve population of turtles

Roadways are the single largest man-made structure in the United States, and their ecological effects are conspicuous. Turtles are among the vertebrate taxa most affected by roadways because of their low vagility and use of roadway habitats. While studies have documented some consequences of transportation infrastructure on turtles and other herpetofauna, many impacts remain unknown. This is particularly true in the case of road-naïve populations, where a lack of previous exposure to roadways could provide insight into potential and related biological and physiological challenges posed to animals within the affected area. In 2013, the Wayne National Forest in southeastern Ohio was bisected by a high-traffic, high-speed, four-lane highway. This previously-intact forest habitat is populated by numerous species and the impacts of the new roadway have not yet been quantified for most, including Eastern Box Turtles (*Terrapene carolina carolina*), a Species of Concern in Ohio and at risk throughout its North American range. Through the use of a control-impact study, we evaluated the potential ecological and physiological effects of proximity to roadways in a road-naïve population of turtles, compared to a population unaffected by paved roads. We employed radio-telemetry and temperature loggers to evaluate space use, movement behaviour, and habitat selection by turtles relative to their proximity to the highway. We used novel techniques in corticosterone testing (using nail keratin samples) to evaluate the presence of chronic stress in animals both near the highway and inhabiting an intact section in the same forest. Spatial analyses provide insight into turtle behaviour, predict specific vulnerabilities to roadways in long-lived herpetofauna, and inform conservation strategies and policy decisions related to wildlife road mortality mitigation efforts.

P2-75 WEIKEL, A*; COLON, E; REDMOND, S; Radford University; *aweikel1@radford.edu*

The effects of Vespa Amino Acid Mixture (VAAM) and 2,4 Dinitrophenol (DNP) on mitochondrial metabolic reactions and the production of ATP

The proton motive force is the result of the inner mitochondrial membrane's electrochemical gradient. This functions by the movement of protons and electrons through a series of electron carrier proteins that provide power for the production of adenosine triphosphate (ATP). The substances being examined in cauliflower mitochondrial isolates, are 2, 4 Dinitrophenol (DNP), a known proton motive force uncoupler, and vespa amino acid mixture (VAAM), a commercially available sports drink derived from Asian giant hornets, a potential coupler. Cauliflower mitochondria were exposed to these substances in three different concentrations (0.3% each, 0.03% each, 0.003% each) to determine if they counteract each other's effects on oxidative phosphorylation. The data collected showed that at high concentrations of VAAM there was an increase in oxidative phosphorylation that led to cellular deterioration even if DNP was present; while at low concentrations the DNP counteracted VAAM allowing the mitochondria to maintain the proton motive force. By measuring the pH levels and ATP production of each treatment group over time, we concluded that VAAM enhanced proton transport which translated into increased ATP production while DNP did not. Mitochondria exposed to 0.003% DNP and VAAM produced more ATP than the mitochondria in the control, but at higher concentrations 0.03% and 0.3% DNP and VAAM, mitochondria produced less ATP than the mitochondria in the control. This suggests that VAAM and DNP affect either the same part of oxidative phosphorylation or closely related aspects.

109-7 WEINER, SA*; HARJO, T; WOODS, WA; STARKS, PT; Roosevelt University, Tufts University, Tufts University; *sweiner02@roosevelt.edu*

Are subordinate roles a conditional strategy? An energy budget of the female roles of Polistes dominula

Polistine paper wasps have long been a model system for studying the evolutionary origins and maintenance of eusociality because they are primitively eusocial and relatively easy to study. Many different explanations have been proposed for the reproductive division of labor in eusocial organisms, but one of the common explanations is reproductive skew models. These models have been largely developed and tested in *Polistes*, but recent tests have found them to be poor predictors of reproductive division of labor in that system. In this research, we suggest that the high energetic cost of solitary founding may play a role in the acceptance of a subordinate role. Energy is known to be limiting for early nests in *Polistes*. We created an energy budget for each role and found that being a solitary foundress is very energetically costly, relative to other foundress roles. Since subordinate foundresses generally start with lower fat stores, this could substantially decrease her success founding alone. If a subordinate foundress would have lower success founding alone, she may not require as high a level of fitness in the subordinate role in order to benefit from adopting that role.

95-1 WEINNIG , A.M. *; DEEGAN , D.F.; CORDES , E.E.; Temple University ; *aweinnig@temple.edu*

Physiological Response of a Cold-Water Coral (Lophelia pertusa) to the Combined Stressors of Climate Change and Hydrocarbon Influence

Lophelia pertusa, a cold-water scleractinian coral, acts as the foundation for deep-sea ecosystems throughout most of the world's oceans, including the Gulf of Mexico. These organisms are under increasing threat due to anthropogenic intrusion into their natural habitats, including ocean change and hydrocarbon extraction. While there are numerous studies highlighting the variable effects of climate change and oil/chemical dispersant exposure on marine organisms independently, there are very few studies focusing on the cumulative effects of both climate change and oil/dispersant pollution together. This study implemented a series of multi-stressor experiments to assess the combined effects of variation in pH, temperature, and oil/dispersant exposures. Four separate experiments exposing *L. pertusa* colonies to various environmental conditions (pH: 7.6 & temp: 9C, pH: 7.9 & temp: 9C, pH: 7.6 & temp: 12C, pH: 7.9 & temp: 12C) and hydrocarbon exposure (oil only, dispersant (Corexit 9500) only, oil and dispersant combined) were performed. *L. pertusa* physiological response was directly assessed by recording polyp behavior, mucous secretion, and tissue loss at four time points during exposure and recovery. Under ambient conditions (pH: 7.6 & temp: 9C) *Lophelia pertusa*'s average health significantly declined during 24 hours of exposure to dispersant alone, but remained relatively constant during exposure to oil or oil and dispersant combined. However, once in recovery, polyp health quickly returned to the pre-exposure health state. Observing the corals' ability to recover after short-term exposures will shed light on their resilience and recovery potential in their natural habitat.

P1-164 WEINSTOCK, JB*; COLLIN, R; Smithsonian Tropical Research Institute, Panama; *jane.b.weinstock@gmail.com*

Larval Response to Seasonal Hypoxia in the Caribbean Sea, Bocas del Toro

Due to the global rise in Earth's average temperature and increased nutrient input, marine ecosystems in the Bocas del Toro region of Panama face increasing stress from seasonal marine hypoxic zones. Hypoxic conditions are well known to stress adult organisms, but little is known about their effect on the planktonic larval stages that sustain these adult populations. We collected weekly plankton samples and water quality data from three sites in Almirante Bay, Bocas del Toro in order to assess larval tolerance to low oxygen in three major marine clades (echinoderms, decapods, and mollusks; here on collectively referred to as "focal taxa"). Samples were collected at 10 and 20 m depth via water pump starting in January 2017. The focal taxa were isolated and counted, and counts were compared to oxygen data to determine if larvae were reduced or absent from layers of hypoxic water. Additional laboratory experiments were conducted on example species from focal taxa (urchin: *Echinometra viridis*; snail: *Littoraria angulifera*; and crab: *Armases ricordi*) to assess larval survival when exposed to low oxygen conditions over 48 hours. Overall, the project aims to identify potential ecological imbalances caused in Caribbean ecosystems by marine hypoxia.

107-5 WEINSTOCK, JB*; MORELLO, SL; CONLON, LM; XUE, H; YUND, PO; The Downeast Institute, Beals, ME, School of Marine Science, University of Maine, Orono, ME, School of Marine Science, University of Maine, Orono, ME; *jane.b.weinstock@gmail.com*

Tidal Shifts in the Vertical Distribution of Bivalve Larvae: Vertical Advection vs. Active Behavior

Some previous studies, though not all, have reported that the vertical distribution of bivalve larvae shifts upward in the water column on flood tides and downward on ebb tides. When observed, such shifts have been interpreted as reflecting the vertical migration of larvae (i.e., an active behavioral process). This interpretation assumes that tidally-driven vertical velocities are insignificant compared to larval swimming speeds, but that assumption may not be valid in all regions. We assessed the tidal vertical distribution of mussel (*Mytilus edulis*) larvae at 5 sites on 8 dates in the Gulf of Maine. We then used a high-resolution coastal circulation model to predict the vertical distribution of passive particles at one site on 4 sample dates. Finally, we conducted a multi-part meta-analysis of published papers on tidal and diel shifts to assess whether variation in the results among studies could be explained by tidal vertical advection via two proxies - tidal amplitude and shelf slope. Our results demonstrate the importance of considering passive processes when evaluating the role that vertical migration behaviors play in the movement of weakly swimming meroplankton.

62-7 WEITZMAN, CL*; SANDMEIER, FC; SNYDER, SJ; TRACY, CR; University of Nevada, Reno, Colorado State University -- Pueblo, Bard College at Simon's Rock; *weitzman.chava@gmail.com*

A Tale of Two "Pathogens": Disease Not Predicted by Infection or Co-infection

An upper respiratory tract disease has been implicated in population declines in North American *Gopherus* tortoise species, and after decades of research, little is known about how the multiple microbes associated with disease interact within the host. We collected upper respiratory samples from populations of four tortoise species and used qPCR to assay for two congeneric *Mycoplasma* pathogens (*M. agassizii* and *M. testudineum*) to detect their relationships with each other and with clinical signs of disease. From our data, no infection status—detectable infection with one or both mycoplasmas, or no infection detected—correlated with clinical signs of disease. However, we detected differences in how these microbes interact with each other in different host species, with some indication of context-dependent facilitation. Prevalence of *M. agassizii* significantly differed among host species, while prevalence of *M. testudineum* did not. Using these samples, we sequenced three genetic markers of *M. agassizii*, but did not find any meaningful differentiation of haplotypes among host species. This research addresses two of five known microbes associated of disease in tortoises; additional presence/absence and infection-load data of other pathogens, as well as data on other members of the upper respiratory microbial community, would allow us to more comprehensively understand the drivers of this disease.

93-7 WEITZNER, EL*; PEARSON, LE; BURNS, JM; LIWANAG, HEM; Cal Poly, San Luis Obispo, CA, University of Alaska Fairbanks, Fairbanks, AK, University of Alaska Anchorage, Anchorage, AK; *emmaweitzner82@gmail.com*

Sealing in the Heat: Modeling Heat Loss Throughout Development in Harp Seals

Harp seals (*Pagophilus groenlandicus*) live in the extremely cold Arctic and rely on thick insulation to maintain thermal homeostasis. Adult harp seals primarily use blubber for insulation, but newborn harp seals rely on a fur coat as their blubber layer develops. This study examined ontogenetic changes in the thermal properties of harp seal fur during submergence. Thermal conductivity, fur thickness, and thermal resistance were measured in water for pelts of harp seal neonates (1d, n=6), thin whitecoat pups (4d, n=3), fat whitecoat pups (9d, n=4), molting pups (2w, n=4), molted pups (3w, n=5), and adults (n=4) and compared to previous measurements made in air. Using these data, we constructed a mathematical model to estimate whole-body conductive heat loss through both the blubber and the pelt. The model simulated a cylindrical body core placed within a cylindrical layer of blubber, inside a cylindrical layer of pelt (skin and fur). Based on the model output, larger animals lose more heat than smaller animals in air ($P<0.0001$), but there was not a significant correlation between mass and heat loss in water ($P=0.085$). When considering heat loss per unit volume, older animals lost significantly less heat than younger animals in both air and water ($P<0.0001$). In addition, heat loss per unit volume was significantly higher in neonate and thin whitecoat pelts in water than in air ($P<0.0014$). Overall, fur function is greatly reduced in water for whitecoats, and this renders neonates and thin whitecoats more vulnerable to extreme heat loss when submerged.

1-2 WELKLIN, JF*; LANTZ, SM; KAHLIL, S; BOERSMA, JP; SCHWABL, HG; KARUBIAN, J; WEBSTER, MS; Cornell University, Tulane University, Washington State University; *jfw96@cornell.edu*

Pairing status and female breeding status influence androgen levels and ornament expression in male Red-backed Fairy-wrens

The role of androgens in regulating behavior and the development of sexual signals has been well-established. However, most research on this topic has focused on explaining how variation in androgen levels during the breeding season matches an organism to its environment. Little is known about what causes variation in androgen levels during the non-breeding season, and the role of androgens in sexual signal expression during this period. Red-backed Fairy-wrens (*Malurus melanocephalus*) live in complex non-breeding social groups, and young males implanted with testosterone during the non-breeding season molt into the sexually-selected red-black plumage. Combined, the complex social environment and the sensitivity to androgens offer an ideal system for measuring how non-breeding social interactions influence androgen levels leading to differential expression or suppression of a sexually selected plumage signal. Here we present results from a series of experiments beginning in the non-breeding season and extending into breeding, showing that date of pair formation prior to the breeding season and female nesting status during breeding jointly influence expression of the sexually selected red-black plumage in males and that this is likely mediated by androgens. Combined, these results show the importance of understanding the connection between an organism's environment and androgens across both non-breeding and breeding seasons.

P2-74 WELLING, EM*; BURNETT, LE; DENSON, M; WATSON, A; MCELROY, E; College of Charleston, South Carolina Department of Natural Resources, South Carolina Department of Natural Resources; *wellingem@g.cofc.edu*

Specific dynamic action in juvenile cobia, Rachycentron canadum: a fast-growing marine fish

Specific dynamic action (SDA) is the rise in metabolism associated with processing a meal and can be a substantial metabolic cost in teleost fishes. SDA is commonly quantified as the peak postprandial metabolic rate, time to peak rate, time to return to standard metabolic rate (SMR), and metabolic expenditure above SMR. Cobia, a popular sport fish, is now widely cultured for food partially due to its fast growth rate. In culture, cobia have been reported to grow up to 8 kg in a year. Protein synthesis has been shown to be the cause for up to 44% of the metabolic increase of SDA in fishes, and many researchers have posited that an increased rate of protein synthesis increases growth potential. A faster and larger SDA may lend a higher rate of protein synthesis that in turn increases the growth potential of fishes. Here we test the hypothesis that cobia exhibit a shorter duration and larger magnitude of SDA than other species reported in the literature. Using respirometry, the oxygen consumption rates of juvenile cobia were measured either after a 24-hour starvation period or immediately after being fed to satiation. Fed cobia did not have a substantially faster nor larger SDA than many values found in the existing literature. From the starved cobia, SMR was 10.6 ± 0.2 (mean ± s.e.) mmol kg $^{-1}$ hr^{-1}, which is similar to SMR values found present in the literature. In cobia, the fast growth may be more related to high food consumption rates than to specialization of digestive metabolism.

P2-157 WELLS, CD*; RAUTU, TS; SEBENS, KP; University of Washington, Friday Harbor Laboratories, University of Washington; *cdwells@uw.edu*

The role of chemical signals in locating prey of Dermasterias imbricata and size-dependent predation on Metridium farcimen

Sea stars play an important role in structuring communities through predation of attached prey species. Sea stars locate their prey through photoreception, mechanoreception, and chemoreception, although the mechanisms behind some of these behaviors are still poorly understood. The leather sea star *Dermasterias imbricata* is a major predator in subtidal communities consuming a diverse assemblage of prey, including competitively dominant species such as *Metridium farcimen*. However, the method for locating prey for *D. imbricata* is unknown. In y-maze trials, we examined the chemosensory abilities of *D. imbricata* in locating four potential prey species, three sea anemone species (class Anthozoa) and one sea cucumber (class Holothuroidea). Additionally, we examined the relationship between sea star size and consumable anemone size through predation trials. Y-maze trials indicate that *D. imbricata* does not use chemical cues in locating its prey and predation trials show a strong relationship between the size of sea anemone that can be consumed and sea star size. There was no relationship between size of sea anemone that will be attacked and sea star size.

P1-149 WERNING, S*; O'KEEFE, FR; MORGAN, DJ; Des Moines University, Marshall University, Calvert Marine Museum; *sarah.werning@dmu.edu*

Giant babies growing very fast: New insights on plesiosaur ontogeny

The recent description of a pregnant specimen of *Polycotylus* demonstrates that plesiosaurs were viviparous, but much of their life history remains unknown. To address this, we gathered morphological and histological data on a growth series of polycotylids from the Pierre Shale of South Dakota. We examined two partial skeletons (an adult and small juvenile) of *Dolichorhynchops bonneri* and an isolated humerus referable only to Polycotylidae. The juvenile skeleton is 40% adult length, close to the birth size estimated for *Polycotylus*, so we predict it is a neonate. The isolated humerus is 28% adult length, and predicted to be a pre-term fetus. Our size-based predictions of relative development are consistent with morphology (bone surface texture, epiphyseal ossification). We also histologically sampled the humeral diaphyses of all three specimens. The adult cortex is thick, dense, and completely remodeled. It grades into a cancellous endosteum and lacks a marrow cavity. The fetal endosteum is similar, but the cortex is thin and consists of unremodeled, radially vascularized, woven-fibered bone, suggesting very rapid deposition. The neonatal endosteum is identical in size and histology to the fetus. Its cortex is thicker and has a birth line, but otherwise is similar histologically. The birth line is not a line of arrested growth, but rather a sudden change in vascular angle, decrease in canal diameter, and increase in bone density, suggesting a slowed growth rate, possibly in response to changes in hydrodynamic forces or diet after birth. The proximity of the birth line to the bone surface indicates that the neonate would have been just under 40% maternal length when born. Our histological data are further evidence that polycotylids were viviparous and birth size was large, and demonstrates that fetal growth rates were very high.

P1-280 WERRY, WD*; PORTER, ME; Wheaton College, Florida Atlantic University; *werry_william@wheatoncollege.edu*

Anisotropic mechanical properties of shark skin vary with denticle density and collagen fiber angle

The epidermis and dermal layers of shark skin have characteristics that increase hydrodynamic efficiency. The denticles are superficial dentin-rich projections embedded in the epidermis that reduce friction drag during locomotion and inhibit algal growth. The stratum compactum, an interior layer of the dermis, is composed of layers of collagen fibers wound in two distinct orientations. Both the denticles and the angle of collagen fibers have been found to vary significantly in respect to anatomical location. The goal of this study was to quantify differences in fiber angle and denticle density (denticles/mm$^{\wedge-2}$) around the circumference of the shark and among species, and to correlate those values with the Ultimate Tensile Strength(MPa), Strain at Maximum Load(%), Toughness(MPa), and Young's Modulus(MPa) of the skin in two directions of uniaxial stress: longitudinal and circumferential. The skin used for these experiments was located between the two dorsal fins, and came from two species, the great hammerhead,*Sphyrna mokarran*, and the tiger shark, *Galeocerdo cuvier*. The skin section was divided into a grid of 9 rows and 3 columns, with each square having the dimensions of 5cmx5cm. Denticle density and fiber angle were assessed under a microscope and quantified using ImageJ. Each square was then divided into 4 dog-bone shaped sections, two at each orientation, and used in tensile testing on an Instron E1000. We found significant differences among species and also by testing orientation. For example, G cuvier was stronger than S. mokarran in both orientations, and both species were stronger when skin was tested in the circumferential orientation. Finally, skin strength decreased with increasing denticle density in both species.

92-1 WESTERMAN , E.L.*; KRONFORST, M.R.; OLSON-MANNING, C.; University of Arkansas, Fayetteville , University of Chicago , Augustana University ; *ewesterm@uark.edu*

Behavior before beauty: signal weighting during mate selection in the butterfly Papilio polytes

Mating displays often consist of multiple signals, either in the same, or different, sensory modalities. These signals may be redundant, or may convey different information. Choosy individuals, or the receivers of these complex mating displays, may differentially weigh multiple signals when selecting a mate. This differential signal weighting in receivers has the potential to influence how signalers behave (and display) during the mate selection process. Males in the female-limited polymorphic butterfly *Papilio polytes* use both female wing pattern and female activity levels when determining whom to court. They find females with mimetic wing patterns more attractive than females with non-mimetic wing patterns, and active females more attractive than inactive females. It is unclear whether females modify their behavior to increase (or decrease) their likelihood of receiving male courtship. In addition, the relative signal weighting of wing pattern and activity is unknown. To address these two questions, we conducted a series of observational studies of a polymorphic *P. polytes* population, with an even sex ratio, in a large butterfly enclosure. We found that males almost exclusively courted active females, irrespective of female wing pattern, and were not more likely to court stationary mimetic females than stationary non-mimetic females. Females exhibited similar activity levels, irrespective of wing pattern. Our results suggest that males weigh female activity levels more highly than female wing pattern when selecting whom to court, even when in a large flight arena with access to multiple inactive females with a preferred wing pattern.

P2-153 WESTERMAN , E.L.*; DIJKSTRA, J.A.; HARRIS, L.G.; University of Arkansas, Fayetteville , University of New Hampshire; *ewesterm@uark.edu*

Climate change, sex, and community state changes in the Gulf of Maine

There is substantial evidence of climate induced phenological changes in terrestrial and freshwater species, however few studies have evaluated the effects of predicted climate warming on phenology in marine environments, or how changes in a species phenology may affect communities along a temperature gradient. We use a dominant cosmopolitan non-native species, *Botrylloides violaceus*, to examine the interaction between seasonal elevations in water temperature and phenology to forecast the effect of climate warming on traits responsible for its distribution and success (i.e., growth and reproduction). We also characterize fouling community assemblage along a temperature gradient to predict the magnitude of the effect of climate induced phenological shifts on annual community assemblage structure. Our results indicate that greater seasonal elevations in temperature will lead to greater asexual reproduction and to multi-annual sexual reproduction of *B. violaceus* in areas that currently have bi-annual or annual reproduction. The output from our model combined with our field studies of succession in fouling communities suggest that in colder environments, fouling and benthic communities may be more affected by climate induced shifts in non-native species' phenology, as they have more free space during the growing season and fewer competitively superior species.

P3-220 WESTFALL, AK*; SCHWARTZ, TS; OAKS, JR; Auburn University, AL; *akw0018@auburn.edu*

The Evolution of Viviparity and the Insulin Signaling Network in Sceloporus Lizards

Vertebrates have transitioned from egg-laying to live birth approximately 140 times across their evolution, 115 of which have occurred within lizards and snakes. In contrast, the mammalian lineage experienced this change one time with the evolution of the mammalian placenta followed by rapid diversification of structures and mechanisms to maintain fetuses. This transition is a major life history change requiring the coordinated evolution of mechanisms to retain the egg, lose the eggshell, and begin provisioning maternal resources to the fetus via a placenta. One major gene network implicated in development, growth, and function of the mammalian placenta is the insulin and insulin-like signaling (IIS) network. Although the IIS network is critical to the placenta in mammals, we currently have a poor understanding of the role of this molecular network in placental function in other clades. There is strong evidence that squamate reptiles have experienced significant positive selection in major regulators of the IIS network such as insulin growth factor 1, insulin, and their receptors, but this selection has not yet been investigated in the context of the repeated evolution of viviparity. *Sceloporus* is a genus of lizards that is ancestrally oviparous but has experienced three unique transitions to viviparity. I have isolated IIS network genes from shotgun genomes of 35 species in this genus. Using molecular evolution analyses, I am testing for unique patterns of selection in IIS network genes that may promote the lability of parity mode in this genus, given the network's important role in mammalian placental function.

77-3 WESTRICK, SE*; VAN KESTEREN, F; BOUTIN, S; HUMPHRIES, MM; LANE, J; MCADAM, AG; DANTZER, B; Univ. of Michigan, Ann Arbor, MI, University of Alberta, Edmonton, AB, McGill University, Montreal, QC, University of Saskatchewan, Saskatoon, SK, University of Guelph, Guelph, ON; *westse@umich.edu*

Impact of maternal stress on stress reactivity and coping styles in a wild mammal

Individual behavioral differences in response to challenging conditions can vary across two different dimensions: the quality of the response (reactive or proactive coping style) and the quantity of the response (hypothalamic-pituitary-adrenal axis activity). However, the relationship between these dimensions has not been extensively explored with relation to developmental stress exposure, an important factor considering the known influence of developmental stress on endocrine structures. Our study examines the impact of maternal stress during the perinatal period on coping behavior and stress reactivity of wild juvenile North American red squirrels. First, to explore the correlational association between behavioral traits and stress reactivity in red squirrels, we used fecal samples and open-field trials on adults in 2008-2010. Next, to assess the causal role of maternal stress, we manipulated developmental stress exposure by feeding mothers glucocorticoids during pregnancy or lactation and tracked juveniles after emergence from the nest. To quantify coping styles of juveniles, we measured three behavioral traits (aggression, activity, and docility) using an open-field trial and docility trial. To assess stress reactivity, we performed dexamethasone and ACTH challenges on juvenile squirrels around the period of weaning and measured plasma cortisol concentrations. This study will further our understanding of how individual differences in behavioral responses may be influenced by endocrine structures shaped by the organizational effects of maternal hormones during the perinatal period.

29-1 WETHEY, DS*; WOODIN, SA; GALASKA, MP; HALANYCH, KM; DUBOIS, SF; ARIAS, A; Univ. of South Carolina, Columbia, Lehigh Univ., Bethlehem, Pennsylvania, Auburn Univ., Alabama, IFREMER, Plouzané, France, Univ. of Oviedo, Asturias, Spain; *dswethey@gmail.com*

Diopatra biscayensis Disjunct Population Not a Relict, Rather Human-Assisted Transport

Explanations of the origins of disjunct populations in dispersing species include 1) hidden population connectivity, 2) contraction of relict distributions and 3) recent long-distance expansion. The onuphid polychaete *Diopatra biscayensis* has its northern contiguous population limit at la Trinité-sur-Mer in the Bay of Biscay, and separated by ~500 coastal km is a disjunct population in the English Channel near Mont-Saint-Michel. We tested the following hypotheses. H1a: the population is actually connected by an unexplored population. This is false because subtidal and intertidal populations share the same geographic range limit in the Bay of Biscay, thus there are unlikely to be hidden populations that provide connectivity. H1b: the disjunct population is within the dispersal range of larvae. This is false because ocean transport modeling indicates that the maximum dispersal distance is less than 50km. H2: the disjunct population is a relict of more permissive times. This is false because hindcasts of geographic distributions of metapopulations indicate that the English Channel population could not have persisted during the shifting climate of the past 1200 years. H3: this disjunct population is relatively new and is associated with long-distance human-assisted transport. This is supported by genetic analysis using a SNP-based RAD tag approach to look at connectivity among populations over the geographic range of the species.

S11-9 WHEELER, QD; College of Environmental Science and Forestry; *qwheeler@esf.edu*

Blank Canvas: The Case for Descriptive Taxonomy

DNA barcodes are a useful tool for identifying species, but are no substitute for descriptive taxonomy. We could turn all the paintings in the Louvre facing the wall, label the reverse of each canvas with a barcode, and accurately distinguish a da Vinci from a Caravaggio, but to what end? Without the unique subject, colors, and composition of such works of art, who cares which is which? Similarly, unless we have knowledge of the characters that make each species unique and reveal their phylogenetic relationships, we miss the most interesting aspects of biodiversity. Like a mapping Mars, a description is a first necessary step toward deep scientific understanding. But in taxonomy, descriptions are more. Species descriptions are not verbal accounts of what organisms look like, but collections of hypotheses about homology. Vertebrates share a backbone, yet the vertebral column of a gerbil and giraffe are visually quite different. Species descriptions, done well, are thus a rich assemblage of rigorously testable hypotheses and, ultimately, the path by which we understand the origins and history of biodiversity. Benefits of describing all species are several. Conservation biologists can measure biodiversity lost or saved. Ecologists can study ecosystems in much greater depth. Entrepreneurs can create a sustainable future through biomimetics, inspired by the adaptations of species. We can tell the story of the origins and history of biodiversity through the fascinating and improbable attributes of species. And we can discover our own humanity by seeing ourselves in phylogenetic context. Before millions of species, biomimetic models, and evidence of evolutionary history are lost, it should be a top priority to complete a global census and description of all species, placing each in its phylogenetic context and mapping its geographic and ecological distributions.

69-6 WHELAN, N.V.*; SIPLEY, B.N.; GALASKA, M.P.; HELMS, B.H.; JOHNSON, P.D.; HALANYCH, K.M.; U.S. Fish and Wildlife Service, Auburn University, Lehigh University, Troy University, Alabama Department of Conservation and Natural Resources; *nathan_whelan@fws.gov*

Populations of Round Rocksnail (Leptoxis ampla), a Federally Threatened Freshwater Snail, Are Surprisingly Distinct

Over 75% of freshwater snails in the U.S. and Canada are considered imperiled. Yet, freshwater snails are critically understudied, particularly those in the family Pleuroceridae. Found in North America, at least 70% of the 162 currently recognized pleurocerid species are at risk of extinction. Furthermore, population genetics of pleurocerids are almost completely unknown, limiting our understanding of pleurocerid biology and hindering management efforts. Here, we examined population genomics of *Leptoxis ampla*, a federally listed snail endemic to the Cahaba River drainage in Alabama. We sampled eight populations from across the range of *L. ampla* and used a 2bRAD-seq approach to target 2,000 loci and assess population connectivity, estimate genetic diversity, and test predictions of expected genetic diversity in headwaters versus main stem reaches. Despite short geographical distances between sampled populations (i.e., <10 km), we identified a surprising lack of connectivity among populations. This suggests that population augmentation through translocation or captive propagation could be problematic, as natural genetic profiles would likely be disrupted. Our study should be a cautionary tale of the potential problems associated with designing management plans, particularly those focused on population augmentations, without considering population genetics of target species.

P2-105 WHELPLEY, JM*; PAULAY, G; RYAN, JF; Whitney Laboratory for Marine Bioscience, University of Florida, St Augustine, FL, Florida Museum of Natural History, University of Florida, Gainesville, FL; *jwhelpley@ufl.edu*

Phylogenomic analysis of 21 species of sea cucumber (Holothuroidea: Echinodermata) and the development of target-enrichment baits for exon capture

Sea cucumbers are the most apomorphic echinoderms: bilaterally symmetrical worms with a reduced skeleton. They have evolved bizarre specializations such as anal suspension feeding, evisceration, sticky Cuvierian tubules that entangle attackers, and a "melting" body wall. They are abundant, ubiquitous in the benthos, from poles to equator, intertidal to the deepest trenches, and include >1700 species in 25 families. They are among the most conspicuous mobile invertebrates on reefs and the deep sea and constitute the largest invertebrate fishery on Pacific islands, with stocks fully depleted throughout the tropics. A recent six gene molecular phylogeny showed substantial conflict with previous morphological-based relationships. Here, we present a phylogenomic analysis of Holothuroidea using 9 unpublished and 11 published transcriptomes. Our data pipeline includes transcriptome-assembly with Trinity, orthology assignment with OrthoFinder, and alignment construction using MAFFT and Gblocks. We conduct both concatenated and coalescent-based phylogenomic reconstruction. In addition, we use our sea cucumber orthogroups and our recently published draft *Australostichopus mollis* genome to design a set of target-enrichment baits for Holothuroidea. The combination of a backbone phylogeny built with hundreds of genes and high-quality baits for target enrichment, will help bring phylogenetic resolution to this fascinating group of animals and provide an important set of resources for systematists to conduct low-cost phylogenetic and population sampling.

44-3 WHITENACK, LB*; KOLMANN, MA; Allegheny College, Univ. of Washington; *lwhitena@allegheny.edu*

Leveraging Extant Shark Tooth Shape to Examine Paleozoic Selachian Morphospace

Historically, extant chondrichthyan tooth shape has been used to make predictions about function and ecology. The shark fossil record is primarily composed of teeth, and likewise, inferences about fossil shark ecology are primarily made based on tooth morphology. However, the link between shark tooth morphology, function, and ecology have recently been called into question. This study examines the link between ecology and tooth morphology in 39 species of extant sharks via redundancy analysis (RDA) of ecological and morphological data. We measured functional, continuous aspects of shark tooth shape, as well as some categorical characters that have been historically used to describe certain morphologies (e.g., cladodont, hybodont). We then compare the occupation of tooth morphospace in 76 Paleozoic selachians to that of extant sharks, as an example of how to leverage quantitative, multivariate data on extant sharks to gain insight into extinct sharks. We found few links between extant tooth morphology and ecological variables such as diet. However, the morphospace analysis yielded some areas of overlap between extant and extinct taxa that are worth exploring, as well as patterns of shrinking tooth morphospace coincident with the Permian-Triassic extinction.

70-4 WHITLOW, KR*; OUFIERO, CO; University of Chicago, Towson University; *kwhitlow@uchicago.edu*

Escape response performance of gymnotiform and closely related body-caudal fin swimmers

Escape response performance is an important aspect of fitness as it aids in survival. Much of the work on escape responses has focused on fish that undulate their body or caudal fin (BCF swimming) or use their paired pectoral fins during routine locomotion. However, fish that rely on the median fins (e.g., anal or dorsal) during steady swimming have not been well investigated, despite their unique modes of locomotion. Gymnotiform locomotion is of particular interest because these fish hold their body steady, undulate only an elongated anal fin to produce thrust during routine swimming, and often have reduced caudal fins, which are a major thrust-producing structure in an escape response. Only one study has investigated the kinematics of escape in a gymnotiform swimmer, and they demonstrated that *Xenomystus nigri* uses axial movements to form a "c-bend" and has a high acceleration relative to similarly-sized BCF swimmers. It remains unclear, however, whether these results hold true across species that employ this swimming mode, including intermediate forms that undulate an elongate anal fin with simultaneous (but lower frequency) body undulations. To investigate the kinematics and performance of escape response maneuvers across gymnotiform-swimming species, we filmed and digitized escapes of *X. nigri* and two other pure gymnotiform swimmers (*Eigenmannia virescens* and *Apteronotus albifrons*), two BCF swimmers (*Devario malabaricus* and *Osteoglossum bicirrhosum*), and two intermediate forms that utilize both body-caudal fin and anal fin undulations (*Chitala ornata* and *Notopterus notopterus*). We found that while body curvatures may differ, phylogenetically-corrected escape performance was unaffected by the distinction between the gymnotiform and BCF swimming modes.

135-8 WHITNEY, CW*; DALEY , MA; NISHIKAWA, K; Northern Arizona University , Royal Veterinary College; *cw729@nau.edu*

Predicting in vivo muscle force in running guinea fowl using a muscle model based on the winding filament hypothesis

Although a large amount of effort has been put towards modeling muscle forces, muscle models are still unable to predict forces during dynamic animal movements, especially with perturbations (e.g. moving over obstacles). In this study, we use a novel model inspired by the winding-filament hypothesis to predict muscle forces in running guinea fowl. Lateral gastrocnemius lengths, activations and forces were measured using sonomicrometry, implanted EMG, and tendon buckles, respectively. Guinea fowl (n = 2) were recorded running on a treadmill during level running and running over 5cm and 7cm obstacles. Muscle morphology parameters included pennation angle, muscle mass and muscle fascicle resting length. The EMG was smoothed, transformed to a percentage of maximum activation, and shifted by a time delay to account for excitation-contraction coupling. The winding filament model (WFM) consists of a contractile element in series with a spring. The contractile element is also in series and parallel with a second spring and damper, representing the titin protein, which wraps around a pulley representing actin thin filaments. Muscle length and activation are inputs to the model, and muscle force is predicted in each time step. The predicted forces were compared to measured forces. The free parameters (n = 6), including an activation factor that varied from trial to trial, were optimized locally and globally using a high-performance computer. Results show that the WFM-based model more accurately predicts forces during perturbed and level gaits ($R2 = 0.72$-0.86) than published results using complex Hill-type models. Biological relevance of the model was assessed by evaluating input parameters, internal model variables, and sensitivity analysis.

P3-263 WIBBELS, T*; NAVARRO, E; ROSAS, M; MONTANO, J; BEVAN, E; NAJERA, B; ILLESCAS, F; PENA, LJ; BURCHFIELD, P; University of Alabama at Birmingham, Gladys Porter Zoo, Brownsville, TX, CONANP, MX, CDEN, Tampaulipas, MX; *twibbels@uab.edu*

Evaluation of Preprogrammed UAV Surveys for Studying the Ecology and Conservation of the Kemp's Ridley Sea Turtle During the 2017 Nesting Season.

New technologies for unmanned aerial vehicles (UAVs) are rapidly evolving and often have potential for enhancing ongoing ecological and conservation research. In the current study, preprogrammed flight plans were evaluated as a method for facilitating and standardizing aerial surveys at the Kemp's ridley sea turtle's primary nesting beach at Rancho Nuevo, MX. Several different commercially available UAV's were evaluated including two models of quadcopters (DJI Phantom 3 Pro and Phantom 4 Pro). All UAVs were equipped with 4K resolution cameras. Video survey flight patterns were developed prior to surveys using Google Maps via a Litchi App for computer tablets. This UAV system proved to be a reliable and consistent method of conducting standardized surveys both for near-shore waters and for the nesting. Although a UAV pilot initiated and monitored all missions via a live HD video feed, the UAV system autonomously flew each survey and recorded high resolution video. Additionally, a Pix4D Capture App was used with these UAVs to conduct preprogrammed photo surveys of the nesting beach topography. The data were then processed with Pix4Dmapper to produce 3-D mapping of the nesting beach. The results included turtle abundance surveys at two week intervals over the 2017 nesting season, and provided a high resolution 3-D topographical mapping of the central 10 km of the primary nesting beach. This research was conducted as part of the ongoing Kemp's Ridley Bi-National Conservation Program.

P3-231 WICKER, VM*; HUND, AK; IBRAHIM, AS; STEPHENS, JQ; TSUNEKAGE, T; LEVIN, II; Agnes Scott College, University of Colorado; *swicker@agnesscott.edu*

The effects of nest mites on variation in nestling telomere length

Telomere length has been implicated as an important predictor of fitness and organismal performance. Previous research has demonstrated that telomere length is heritable, but sources of environmental variation and their effects on telomere length remain largely unexplored. In this study, we examined the effects of nest parasites on the relative telomere length of North American barn swallow nestlings (*Hirundo rustica erythrogaster*). We utilized an egg cross-foster design in order to separate the genetic and environmental factors influencing nestling telomere length. This was done by switching eggs between synchronously laid nests after the penultimate egg was laid but prior to the initiation of incubation. We then added 100 nest mites to half of the experimental nests and removed mites from the other half via sterilization with a heat gun. A blood sample was taken from the nestlings nine days after hatching for molecular sexing, quantification of relative telomere length, and for parentage analysis using microsatellite markers. We used qPCR to quantify relative telomere length. We predicted that nestlings in parasitized nests would have relatively shorter telomeres compared to nestlings raised in sterile (mite-free) nests.

P3-123 WICKSTEN, MK; Texas A&M University; *Wicksten@bio.tamu.edu*

Deep Discoverer Gives a New View of Deep Decapods

Most decapod crustaceans living at 700 m or deeper are known only from dead specimens, whose habitat and behavior in life remains unknown. The NOAA ship *Okeanos Explorer* deploys a two-part remotely operated vehicle system: the camera sled *Seiros* and the main collecting and photographic vehicle *Deep Discoverer* (DD2). The ROV system can send live video and still camera feed by satellite to interested scientists on shore. Able to focus on subjects in detail, the DD2 has transmitted remarkable images of diverse invertebrates on rocky substrates. Among the latest images are one showing presumed filter feeding by a stylodactylid shrimp, a consistent association between certain homolid crabs and sea anemones, a peculiar "gait" in parapagurids carrying sea anemones, host specificity in various chirostylid squat lobsters and thorid shrimps, but less specificity in shrimps of the genus *Bathypalaemonella*. The DD2 has limited collecting capability so many of the decapods remain unidentified to species or even genus. The diversity of associations among these decapods on seamounts and other hard surfaces hints at complex deep ecosystems and warns of potential damage from deep-sea fishing or mining.

130-1 WILCOX, SC*; CLARK, CJ; Univ. of California, Riverside, Univ. of California. Riverside; *swilc002@ucr.edu*

Sexual selection for flight performance in hummingbirds

Sexual size dimorphism is a widespread phenomenon in animals. In most cases, in birds and mammals, males are larger than females. However, in several species the reverse is true: females are instead the larger sex (female-biased size dimorphism). One hypothesis for the occurrence of small males, relative to females, is the male agility hypothesis which posits that selection for vigorous, agile courtship performances drives the evolution of small male size. Males of several hummingbird species perform seemingly agile flight behaviors during courtship. To test the aerial agility hypothesis we compiled size data from the literature along with courtship-display and hovering wingbeat frequencies for male and female hummingbirds. This allowed for analyses of scaling patterns that illustrate how selection for courtship performance coincides with small male size and elevated male hovering wingbeat frequency. Hummingbird hovering wingbeat frequency scales negatively with body size. For mass, the allometric exponent of -0.597 compares to -0.269 in other birds (Rayner, 1988). For wing length, the allometric exponent of -1.25 compares to -1.03 in small passerines (Greenewalt, 1975). Furthermore, within the Mellisugini clade, some males utilize particularly high hovering wingbeat frequencies for their sizes, and males of these species tend to be smaller than their female counterparts. Small male size and elevated male hovering wingbeat frequencies in this clade have evolved due to selection on males for exaggerated wingbeat-frequency courtship displays.

79-3 WILCOXEN, TE*; MIHALKANIN, E; BRINEGAR, J; CHESKO, S; SEITZ, J; NUZZO, JT; Millikin University, Illinois Raptor Center; *twilcoxen@millikin.edu*

Correlations between early-life stressors and physiological condition in juvenile birds of prey.

Though multiple studies have explored the effects of stress on symmetrical growth in birds over short periods of time, there have been comparatively fewer long-term measurements of how stress affects asymmetrical growth, particularly in birds of prey. Fluctuating asymmetry (FA) is known to occur as a product of poor early-life conditions and experience with persistent stressors. One way to quantify stress in birds is to measure corticosterone (CORT) in feathers. Birds deposit CORT into their feathers when first growing the feathers as nestlings and also during molt, but they cannot deposit CORT after that feather is grown. We examined FA in juvenile birds, from four species, admitted to the Illinois Raptor Center either as orphaned nestlings or for rehabilitation and concurrently measured CORT in feathers. We also measured levels of lead in the blood of each bird to explore a possible link between toxicology and stress or symmetrical growth. Finally, we explored additional downstream consequences, such as parasite prevalence in birds with varying degrees of asymmetry. We found that for juvenile birds, feather CORT showed a positive, linear relationship with asymmetry. However, there was no significant relationship between CORT and asymmetry in adult birds. Blood lead levels were significantly correlated with fluctuating asymmetry, and fluctuating asymmetry was a significant predictor of parasite prevalence for all species. Overall, our findings add to the existing body of evidence that early-life stressors can have long-lasting consequences for birds.

P3-178 WILKEN, AT*; MIDDLETON, KM; SELLERS, KC; COST, IC; HOLLIDAY, CM; University of Missouri-Columbia; *atwxb6@mail.missouri.edu*

Finite Element Analysis of the Savannah Monitor, Varanus exanthematicus, and its Implications for Lepidosaur Cranial Kinesis

Many lizards, birds and other vertebrates exhibit cranial kinesis or movement among skull bones. Although the skeletal anatomy of some cranial joints are understood, how these joints are built histologically and how they are loaded during feeding remains poorly understood. To determine the impact of soft, connective tissues in the skulls of kinetic vertebrates we developed a Finite Element model of *Varanus exanthematicus* that mimics different types of kinetic linkages including fused, synovial and ligamentous joint types. Muscle force magnitudes were calculated from physiological cross-sectional area estimates, muscle attachments were mapped and several muscle force load patterns were created using Boneload computational methods. These load cases allowed us to better elucidate the role of the protractor and pterygoideus musculature in the palate as well as the skull in general. These load cases were applied to models with different soft tissue linkages to better learn the role of soft tissues and the protractor musculature in cranial kinesis. Modeling joints as non-bony soft tissues produced deformations that more closely approximated known in vivo feeding kinematics. This concordance affirms the model's ability to mimic feeding mechanics; therefore, the methods used to develop the varanid model can be used to test hypotheses about the functional and evolutionary variation of cranial kinesis in not only lepidosaurs but also other vertebrates.

S3-3 WILKINSON, Mark*; GARBOUT, Amin; MOHUN, Samantha M; The Natural History Museum, London; *m.wilkinson@nhm.ac.uk*
The visual system of caecilian amphibians
Caecilians are an ancient radiation of mainly fossorial amphibians with reduced visual systems (their name being a reference to their being blind). Adult caecilian amphibians eyes are small, covered by skin and sometimes by bone, with retinal cells that may only contain rod opsins, associated with scotopic (dim light) vision. Here we give an overview of what is known of the structure, function and evolution of the caecilian visual system. Morphological comparisons suggest different degrees of visual system reduction probably associated with different degrees of dedicated subterranean burrowing lifestyles, with independent losses of many components of the visual system or their modification to serve other functions. Spectral sensitivities of some caecilian photoreceptors have been determined with microspectrophotometry and visual pigment genes sequenced. Rod opsins regenerated in vitro with 11-cis retinal give pigments with spectral sensitivity peaks at 493nm or below, short-wavelength shifted in terms of the maximum absorption of light when compared with other amphibian lineages. The significance of this shift and its molecular mechanism remain to be determined. Because of the obvious potential for regressive evolution to lead to convergent losses that might confound morphological phylogenetics, comparative morphological data on caecilian eyes has been a focus for studies of methods of character coding and of detecting character independence. Additionally, these data have been used to address the utility of discrete character data in analyses of disparity. However, there are many inaccuracies in the underlying observations due in part to histological artefacts. We illustrate some of these problems and our recent attempts to use non-invasive X-ray microscopy (ZEISS 520 Versa) to provide more reliable observational data for use in such synthetic investigations.

45-3 WILLIAMS, CT; Univ. of Alaska Fairbanks; *ctwilliams@alaska.edu*
Seasonal Reproductive Tactics: Annual Timing and the Capital to Income Breeder Continuum
Tactics of resource use for reproduction are an important feature of life-history strategies. A distinction is made between ‘capital' breeders, that finance reproduction using stored energy, and ‘income' breeders, which pay for reproduction using concurrent energy intake. To date, much of the research on capital and income breeding has focused on the diversification among species in tactics of resource use. However, plasticity in the allocation of capital towards reproduction is common in many species. I will discuss 1) how this plasticity provides resilience to environmental change and 2) how plasticity might be linked to the endocrine and neuroendocrine systems that control the reproductive axis. I argue that better delineating these endocrine and neuroendocrine circuits may help in identifying target genes for monitoring adaptive genetic responses to environmental change. Additionally, reproductive phenology, fecundity, and energy allocation strategies are all interconnected and, to be fully understood, these life-history traits should be examined within a single framework rather than in isolation.

41-2 WILLIAMS, TD*; GILLESPIE, C; SEROTA, M; Simon Fraser Univ., Burnaby; *tdwillia@sfu.ca*
Complexity of Activity During Parental Care: Does This Represent "Exercise" or "Training?
Analysis of parental behavior during chick-rearing is often focused on activity at the nest, measured as provisioning rate Furthermore, data are often obtained only from "successful" birds. We used an automated radio tracking system to measure total activity in female European starlings (Sturnus vulgaris) 24/7 during late incubation and chick-rearing in both successful and failed birds. Tracking data revealed novel, aspects of parental behavior, e.g. a) large inter-individual variation in activity during incubation, b) putative nocturnal foraging bouts, but c) high repeatability of individual variation in activity across breeding stages. In successful birds, total activity was not correlated with provisioning rate and we suggest that this is because only a component of total activity is directed towards, or required for, successful rearing of chicks. Additional activity of parents appears to constitute "self-maintenance" behaviour, i.e. "activity" which might explain different ‘strategies' for maximizing fitness. Nest failure rates were higher in second broods than in first broods, but more birds failed early (before hatching) in first broods, i.e. parents persisted with parental care for longer in second broods before nest failure. For first broods, there was no difference in diurnal or nocturnal activity level of failed vs. successful birds during incubation, but birds that failed had lower total activity levels during chick-rearing even prior to breeding failure. Our activity data suggest that natural populations harbor "couch potatoes" and "athletes". We discuss whether nocturnal activity, or off-nest activity during incubation, represent foraging for self-maintenance or opportunities for exercise allowing birds ‘to get in shape' ready for chick-rearing.

62-2 WILLIAMS, JD; Hofstra University, Hempstead, NY; *biojdw@hofstra.edu*
Parasitism by trematodes negatively impacts byssal thread production and attachment strength of mussels
Mussels are ecologically and commercially important members of coastal systems. Along the east coast of the United States, the blue mussel *Mytilus edulis* is commonly infected (typically 30-60% prevalence on Long Island, NY) by the digenean trematode *Proctoeces maculatus*. This trematode can complete its entire life cycle within mussels and often reaches high intensity levels, causing the disease known as "orange-sickness." These trematodes negatively impact reproduction of the mussels, but little research has been done to examine the effects of these parasites on other aspects of mussel biology such as byssal thread production. Byssal threads are vital to maintaining mussels in their turbulent environments and some stressors (e.g., lowered pH) are known to influence their material properties. In the present work, the impacts of *P. maculatus* on the total number of byssal threads produced and attachment strength of mussels collected from Long Island, NY were tested. Over one week of isolation in the laboratory, mussels with high parasite intensity (>10 sporocysts/6mm biopsy) produced a significantly lower number of byssal threads than mussels with low parasite intensity (<10 sporocysts/6mm biopsy). In addition, mussels with high parasite intensity had significantly lower attachment strength than mussels with low parasite intensity. The findings indicate that the physiological impacts of *P. maculatus* on mussel hosts need to be more fully examined, especially considering that the range of this parasite appears to have expanded northward in recent years. Such parasites may have synergistic effects with other environmental stressors, making mussels more susceptible to die-offs.

BART-1 WILLIAMS, Caroline M.; Univ. of California, Berkeley; *cmw@berkeley.edu*

Cold truths: Evolutionary impacts of winter on terrestrial ectotherms

Climate change research historically focused on summer, and winter climate change was considered mostly beneficial due to amelioration of damaging cold. It is now becoming increasingly apparent that variation in winter conditions drives responses of many terrestrial organisms to climate change in complex ways, and that a mechanistic understanding of the impact of winter conditions is essential to identify vulnerabilities to climate change. Throughout my career, I have tried (and frequently failed!) to apply the integrative approach of George Bartholemew to a range of ectotherms, mostly insects, to discover the evolutionary impacts of winter. I have shown that winter warming negatively impacts many butterflies and moths by increasing metabolic rates and energy drain, which can reduce subsequent reproduction. Selective pressures imposed by variable winters can reduce thermal sensitivity of metabolism, leading to better performance over winter and in the subsequent growing season. Using field- and lab-based reciprocal transplant experiments, I demonstrated that winter conditions drive local adaptation of insect populations, suggesting that changes in winter conditions may cause population declines across the range. Using *Drosophila melanogaster*, I demonstrated that cold adaptation increases metabolic costs due to increased flux through central metabolic pathways, allowing cold hardy flies to synthesize protective molecules more rapidly. This suggests a mechanism through which cold stress shapes evolution of metabolic pathways, possibly contributing to large-scale biogeographic patterns in life histories previously attributed to selection on growing season performance. My current research focuses on the role of snow in driving ecology and evolution of insects, and elucidating the biochemical and metabolic origin of life history trade-offs.

P2-203 WILLIAMS, M*; JACKSON, BE; Longwood Univ.; *mccoy.williams@live.longwood.edu*

Kinematic Variation During Wild Blue Jay Landing Flights

Flight imposes numerous mechanical and evolutionary constraints on those animals that possess the ability, which may also imply kinematic constraints. Most of our understanding derives from laboratory studies, often of birds in wind-tunnels performing steady flight, or in other artificial scenarios. However, flight evolved and is routinely performed in wild and variable settings where successful take-offs and landings are critical, and variation in kinematics may be expected. We used three GoPro Hero4 Black cameras to film (240 fps) wild Blue Jays (*Cyanocitta cristata*) approaching and departing bird feeders in Farmville, VA, U.S.A. After calibrating the three-dimensional volume with a wand of known length, correcting for lens distortion, and synchronizing the videos using the audio tracks, we were able to reconstruct the 3D positions of ten points on the birds' bodies and wings within the filming volume (~ 1 x 1 x 3 m). We calculated several kinematic factors, which varied among flights, but from which basic mechanical hypotheses can be examined. Consistently performed rapid pitch-up maneuvers have been linked to energy dissipation in past controlled experiments. However, our field observations on just 5 flights show extensive variation in angle of attack and stroke plane angles used while landing. For example, the wing stroke plane angle during the last wing beat prior to landing ranged from positive 7 degrees (upward) to negative 40 degree (downward). This variation suggests that even within a species there are multiple kinematic solutions to the mechanical problem of landing, and the optimal solution likely depends on variation in approaching speeds and angles (outside of our filming volume), behavioral input, or regular variation between individuals of the same species.

P2-270 WILLIS, M A*; SANE, S; Case Western Reserve University, Cleveland, USA, National Institute of Biological Sciences, Bangalore, India; *maw27@case.edu*

Wing-beat induced flows and odor tracking in insects.

The odor signal detected by a plume tracking animal results from the interaction of: 1) environmental turbulence flowing over the odor source, 2) the size, shape and position of the odor sensors on the tracker's body, and 3) the form of locomotion used by the tracker. The flapping wings of flying insects generate an additional directional flow, usually from head-to-tail over the animal. Depending on the speed of the wind in which they are flying, this wing-beat induced flow can account for nearly 100% of the flow over the odor-detecting antennae (i.e., hovering or experimentally tethered). To better characterize wing-beat induced flows and how they might influence detection of the odor plume, we used a hot-wire anemometer to measure the wing-beat induced flows near the antennae of tethered flying *Manduca sexta* moths across a range of wind speeds. Wing beat induced flows can be divided into two components, 1) the mean flow, or average flow speed from front-to-back over the moth, and 2) the periodic flow, or the regular rhythmic increases and decreases in flow caused by the up and down stroke of the wings. As would be expected, the mean induced flow increased each time we increased the wind speed. Thus, the moth was always generating flows that were slightly faster than the wind speed. The periodic flow accounted for 100% of the induced flow in still air. As the ambient wind speed increased, the proportion of the flow over the antennae accounted for by the periodic wing beat induced flow decreased. The range of wind speeds where the influence of the periodic component of the induced flow is strongest coincides with the range of wind speeds most likely to be encountered by these moths during their activity periods in nature. Electrophysiological recordings from the antennae show the effect of wing beat induced flows on the plume structure detected may be fairly subtle.

59-7 WILMSEN, SM*; ROMANO-OLIVIA, DC; RECTOR, SE; MARTIN, AS; DZIALOWSKI, EM; University of North Texas; *sarawilmsen@my.unt.edu*

The Effect of Acclimation to a Fluctuating Temperature on CO_2 Production During and After Exercise in the Desert Tarantula Grammastola rosea

Thermal metabolic compensation is a well-established theory stating that ectotherms acclimated to a lower temperature will have a higher metabolic rate at a given temperature than those acclimated to a higher temperature. This partial compensation of MR increases overall fitness at low temperatures for these animals. When thinking about acclimatization, it is tempting to forget that the natural world is rarely at a constant temperature. This is especially true for desert environments that can easily see a range of 15-20 °C in a 24 hr period. Temperature change has far-reaching impacts on MR and exercise performance through changes in reaction rates and enzyme activity. In this study *Grammastola rosea*, a small tarantula endemic to the Atacama Desert, was used to investigate the implications of a fluctuating environment on SMR and carbon dioxide production during and after exercise. We used flow-through respirometry to examined standard metabolic rate (SMR) and MR during exercise at 15 °C and 30 °C following acclimation to 15 °C, 30 °C, and a treatment fluctuating between the two temperatures. As expected, the lower temperature acclimated spiders had a higher SMR than those acclimated to the higher temperature. However, the 15 °C spiders produced less CO_2 during and after exercise than the 30 °C spiders. In the fluctuating treatment, spiders had an even higher SMR at both temperature than other treatments and had the highest CO_2 production post-exercise at both temperatures. This study raises questions about the effects of acclimation to a fluctuating temperature on the overall physiology of the animals and has possible implications on the effect of climate change on small ectotherms.

114-3 WILSHIN, SD*; BARTLAM, H; HUBEL, T; HAILES, S; WILSON, A; Royal Veterinary College, University College London; *swilshin@rvc.ac.uk*

Zebra can navigate between resources without having to use the same track every time, tracks in the right direction will do

All free-ranging animals need to be able to move efficiently between the resources they require; poor navigation wastes energy and time, potentially reducing environmental fitness, and ultimately puts an animal at risk of death from dehydration and starvation. Here we show that zebra navigate between these resources (over a range of around 100 square kilometres) not by following a small number of specific paths, but rather by moving along sets of parallel paths, all without long range landmarks to aid navigation. We do this through the application of a model based on a radial basis function network to GPS tracks of zebra movement in the Moremi Game Reserve, Botswana. The proposed model performs better than assuming uniform angular distribution of trajectories with a significant improvement in an Akaike Information Criterion. The scale at which neighbouring trajectories are informative was found to be large compared with the typical track separation. These results are inconsistent with the zebra following only a single memorized track between destinations but rather imply the use of any of the available tracks which allow progress to a destination. This suggests zebra have the ability to navigate without the requirement to return to the original track if perturbed.

P2-179 WILSON, LT*; COUGHLIN, DJ; Widener University, Chester, PA; *ltwilson@widener.edu*

Thermal Sensitivity of the Mechanics of Red Skeletal Muscle in Rainbow Trout

The North American rainbow smelt (*Osmerus mordax*) and rainbow trout (*Oncorhynchus mykiss*) display impressive thermal acclimation to cold water, which aids their ability to survive in winter. Changes in the environmental temperature can affect different physiological properties of red or slow-twitch skeletal muscle including force generation, relaxation, shortening velocity, and mechanical power. Trout and smelt show acclimation responses in these properties when exposed to cold temperatures over extended periods of time. How will these fishes respond to a warming environment that results from environmental shifts due to climate change? The goal of this study was to examine the effect of a warming environment in rainbow trout swimming performance and muscle mechanics. Maximum steady swimming speed was determined in swim tunnel studies, and contractile properties were determined in muscle physiology experiments. Thermal sensitivity, the change in physiological parameters in response to acute changes in temperature, was determined in trout muscle as well. This research will hopefully reveal how trout will respond to a warming environment due to climate change.

56-3 WILSON, CA*; FIELD, KA; REEDER, DM; LILLEY, TM; Bucknell University, University of Liverpool; *caw050@bucknell.edu*

Pathogen prevalence in little epauletted fruit bats in South Sudan and Uganda

Bats can serve as reservoir hosts of several emerging infectious diseases, such as those caused by henipaviruses, Marburg and Ebola filoviruses, and SARS and MERS coronaviruses. The African little epauletted fruit bat, *Epomophorus labiatus*, is a likely reservoir host for several pathogens with zoonotic potential. *Epomophorus labiatus* is peridomestic, commonly found near human settlements and may be hunted for food, allowing for possible disease spillover from bats to humans. In addition to viral infections, this species is also known to have high loads of *Hepatocystis* spp. malarial parasites. To further explore their pathogen burden and their potential importance in zoonoses, we determined the prevalence of various pathogens, such as lyssaviruses, malarial parasites, and *Bartonella* spp., in *E. labiatus* from South Sudan and Uganda. We compare pathogen prevalence across sex, age, season, reproductive status to better understand spillover risk. We hypothesize that bats with high parasite loads will be co-infected with other pathogens as infection with one pathogen may lower immune responses against another pathogen. Furthermore, we hypothesize that sex, reproductive status, and season will affect pathogen prevalence and co-infection profiles. When environmental conditions are challenging, resources may be shifted from immune processes to other physiological systems. Thus, we predict higher pathogen prevalence during the dry season. Similarly, as pregnancy may represent an immunosuppressed state, we predict higher pathogen prevalence during pregnancy compared to that of non-reproductive females.

P1-81 WILSON, TJ*; GRUNWALD, JT; ROMAGNOLO, DF; SELMIN, OI; PROPPER, CR; Northern Arizona University, University of Arizona, University of Arizona; *tomoko.wilson@gmail.com*

Environmentally relevant sodium arsenite has no effect on larval zebrafish behavior

Arsenic (As) is a metalloid commonly present in the aquatic environment as a result of natural and anthropogenic activities. It is a known neurotoxin that causes cognitive deficits, neuropathy, and altered brain anatomy. Current literature on As exposure and behavior in the developmental and toxicological zebrafish model has focused on midrange doses often above those found regularly in the environment. In this experiment 48 hours post fertilization zebrafish larvae were exposed to environmentally relevant levels of sodium arsenite at 0, 0.1, 1.0, or 10 µM for eight days. At the end of the treatment larvae were recorded using the DanioVision system for 30 minutes each during acclimation, lights on, and lights off.. Cumulative time spent in inner and outer zones, swim velocity, and total distance covered were measured and analyzed using a one-way ANOVA. There were no significant differences in any of the tested measures suggestive of no neurotoxic effect at low level exposure. The exposure levels fell both under and above the EPA's and the World Health Organization's As guideline of 10 ppb (0.13 µM), and were well within surface water and groundwater levels commonly found in many parts of the United States. These results provide evidence that short-term, low-level As exposure may not influence early development neurotoxic behavioral outcomes in fish.

P1-201 WILSON CARTER, A*; SADD, BM; TUBERVILLE, TD; PAITZ, RT; BOWDEN, RM; Illinois State University, University of Georgia; *amandawilson1213@gmail.com*
Sometimes less is more: focusing on heat waves improves estimates of turtle sex ratios
Many turtles possess temperature-dependent sex determination, which may increase their susceptibility to climate change associated thermal variability. Despite substantial efforts, our ability to accurately estimate sex ratios from temperature traces in the field is limited, possibly due to a focus on average temperatures across a lengthy period of development. Recent evidence suggests that sex determination is sensitive to brief bouts of exposure to warm temperatures (e.g. heat waves), thus traditional methods of estimating sex ratios that utilize aggregate statistics across the entire middle third of development may be obscuring important biological cues. We report the results of a new model, the Duration Model, for estimating sex ratios from soil temperature traces. The Duration Model builds upon existing models to estimate sex ratios, incorporating the effects of shorter periods of development where temperatures are sufficient to set gonadal fate, as determined from our empirical findings. We compared sex ratio estimates from the Duration Model to a long-term database of field sex ratios, and found that the Duration Model outperformed existing models. We used the Duration Model to characterize historic sex ratios in multiple populations and to determine the relative contribution of seasonal thermal shifts to sex ratios. The Duration Model significantly enhances our ability to predict sex ratios from field soil temperatures, and may facilitate more accurate predictions of how population offspring sex ratios will change under future climates.

99-4 WILSTERMAN, K*; BALLINGER, M; WILLIAMS, CM; Univ. of California, Berkeley; *kwilsterman@berkeley.edu*
Winter dormancy in insects and mammals: A new, comparative framework
In seasonal environments, many organisms enter a programmed state of developmental arrest in which energy use is reduced and stress hardiness up-regulated. Insect diapause and mammalian hibernation are well-studied examples of dormancy within animals. Though there is conceptual and functional overlap between these groups, there is no comprehensive framework for comparing or contrasting these processes across taxa. We present a shared framework that lays out a series of dynamic phases that animals traverse during dormancy: preparation, initiation, maintenance, potentiation, and activation. We discuss some of the functional processes that operate during each phase and the utility of the framework for investigating and understanding species responses to variable climate conditions. Finally, we use the framework to identify emerging opportunities that arise from a cross-taxa consideration of programmed dormancy. We expect that this framework will be broadly useful for addressing questions related to overwintering eco-physiology. Moreover, the framework may be used more broadly to develop more integrative, comparative thinking across other types of programmed dormancy, including plants, invertebrates, and non-mammalian vertebrates.

P1-139 WILTSE, MS*; WILLIAMS, SE; WEN, AHC; CHISHOLM, KL; PAPATHEOFANIS, CF; REZK, CA; VALENZUELA, JL; COHN, BA; SCHMITZ, L; Claremont McKenna, Scripps, and Pitzer Colleges; *sage.wiltse@gmail.com*
Evolution of Visual Acuity and Trophic Specialization in Labrid and Pomacentrid Coral Reef Fishes
Coral reef fishes, one of the most speciose assemblage of vertebrates, display an enormous diversity in terms of habitat preferences, diel activity patterns, and trophic specializations. Such large ecological diversity is coupled with disparate demands for vision, making coral reef fish a uniquely well-suited group to study evolutionary interactions between photic environments and the visual system. For example, fishes feeding on small zooplankton have frequently been hypothesized to have higher visual acuity than their relatives feeding on benthic prey, but existing evidence is inconclusive. We tested this hypothesis by following predictions of physiological optics, and collected data on lens diameter (a proxy of focal length) and the density of retinal ganglion cells. Both features can be combined into a physiological estimate of visual acuity. Our results for 19 labrid and 7 pomacentrid species, representing six independent transitions between plankton/benthic feeding, demonstrate that visual acuity does not differ between trophic specialists. However, most of the analyzed species, zooplanktivore or not, are theoretically able to detect zooplankton at a normal strike distance, as shown by optical modeling. In addition, the majority of the zooplanktivores (all plankton-feeding pomacentrids and 1 out of 3 plankton-feeding labrids) have a centrally located area centralis as opposed to the horizontal streak of high density ganglion cells commonly seen in benthic feeders. While our results suggest differences in retinal topography associated with trophic specialization, the evolution of visual acuity is likely controlled by additional factors other than diet.

S6-8 WINGFIELD, JC; Univ. California, Davis; *jcwingfield@ucdavis.edu*
Environmental Endocrinology: Field and Laboratory Investigations of Mechanisms in Life Cycles.
All organisms must time their life cycles appropriately and organize life history stages into temporal sequences that enhance fitness in a changing environment. The endocrine system plays a major role in transducing information from the environment into morphological, physiological and behavioral responses appropriate for the time of year. These perception, transduction, response pathways via neural and endocrine mechanisms are being revealed. Whereas many common mechanisms (evolutionary constraints hypothesis) are emerging, there is a growing realization that there may be unique pathways (evolutionary flexibility hypothesis). Field investigations (field endocrinology) over the past 45 years have revealed patterns of hormonal responses to environmental changes, physical and social, that could not have been anticipated from laboratory investigations alone. These patterns include differences at population and individual levels that have enabled new insights into acclimation and adaptation to environmental transitions. The number of species studied under natural conditions has grown exponentially in recent years to include all vertebrate classes and many invertebrates as well. These data are now driving evolutionary perspectives and with the advent of comparative genomics a new and exciting era of evolutionary endocrinology is developing. This symposium gives a timely overview of where the field stands now and where it is likely to go in the future.

28-8 WINNIKOFF, JR*; HADDOCK, SHD; THUESEN, EV; WILSON, T; Univ. of California, Santa Cruz, Monterey Bay Aquarium Research Institute, The Evergreen State College, The Evergreen State College; *jwinnikoff@ucsc.edu*

Grace Under Pressure: Cloning and Hyperbaric Characterization of Pyruvate Kinase from Deep-Sea Ctenophores

Hydrostatic pressure has a strong influence on the physiology of deep-sea animals, since many proteins do not function constantly over a pressure range of hundreds of atm. Ctenophores, or "comb jellies," are gelatinous animals that have colonized most of the oceanic water column, from the surface to ~7 km deep, where ambient pressure is about 700 atm. We have begun to assess the functional diversity of ctenophore metabolism by cloning the glycolytic enzyme pyruvate kinase (PK) [EC 2.7.1.40] from several species living across a depth gradient. We then expressed these PK orthologs in *E. coli* and assayed their activity under pressure. PK was chosen based on its putatively adaptive pressure resistance in deep-sea fishes and in preliminary studies on whole ctenophore homogenates. The pressure/activity data reported here are novel with respect to invertebrates, and offer a ready comparison to fish datasets. Overproduction of enzymes from deep-sea invertebrates for comparative physiology presents both benefits and challenges. Major advantages are (1) the option of site-directed mutagenesis, which can be used to reveal sequence features that confer pressure resistance, and (2) the ability to produce unlimited amounts of protein from a single small individual, rather than having to collect rare animals and pool substantial biomass. The most pressing challenges are (1) producing a fully native amino acid sequence, i.e. precisely as found in the animal, with no artificially appended residues, and (2) preserving the activity of heat-labile products. We fulfilled both these requirements by incorporating a highly specific protein tag cleavage system into a cold-shock expression plasmid. The resultant vector is useful for studying protein evolution in cold-adapted organisms.

83-4 WINSTEAD, D; OHDERA, A*; MEDINA, M; LAJEUNESSE, TL; Pennsylvania State University; *auo140@psu.edu*

Symbiodinium proliferation inside a cnidarian host vessel are competitive and dynamic

Most mutualisms involving cnidarians and symbiotic dinoflagellates exhibit high specificity and partner stability. Whether this specificity and stability is conferred/regulated more by the host or symbiont remains largely unknown. The upside-down jellyfish, *Cassiopea xamachana*, is generally found to host *Symbiodinium microadriaticum* in nature. However under sterile laboratory conditions, this animal is capable of forming viable symbioses with a multitude of different *Symbiodinium* species. We took advantage of *C. xamachana's* promiscuity under controlled experimental conditions to examine the outcome of symbiont competition within the host. Aposymbiotic polyps of *Cassiopea xamachana* polyps were exposed to various pairwise combinations of different species of *Symbiodinium*, with each symbiont introduced at equal and skewed cell proportions. The infected polyps were cultivated for 4-5 weeks until metamorphosis. Following strobilation, the relative abundances for each symbiont pairing were determined among individual juvenile jellyfish using qPCR. Large differences in infection dynamics were observed depending on the opposing *Symbiodinium* spp. used, indication that competition between symbionts dictates host-symbiont specificity in nature.

S11-10 WINSTON, J E; WINSTON, Judith; Smithsonian Marine Station, Fort Pierce, FL; *judithewinston@gmail.com*

21st Century Biological Nomenclature—the Power of Names

Nomenclature and taxonomy are complementary aspects of the study of biodiversity. However, the two are often confused even by biologists. Taxonomy is the science of identifying, describing, and determining relationships of organisms from species to higher taxa. Nomenclature is a system of giving names to organisms based on rules established for the process. European exploration from the 15th through the 18th centuries resulted in the accumulation of a wealth of new organisms to be named and described by naturalists. While adoption of a system of binomial nomenclature in the last half of the 19th century helped speed up the process, by the middle of the 19th century the turmoil resulting from differences in taxonomists' procedures and philosophies meant it was necessary for codes of nomenclature to be developed to regulate the process of naming. By the early 20th century International Codes of Nomenclature were in place for plants (ICBN) and animals (ICZN). These codes worked reasonably well through most of the 20th century, but the rapid development of electronic communications and publication at the end of the century resulted in pressure to revise the codes of nomenclature to allow for partly or all electronic publication in the hope of speeding up description of new taxa in what was rapidly becoming an age of biological extinction. This has been accomplished for the Zoological and Botanical Codes. For example, ZooBank, begun in 2008, had registered 188,908 nomenclatural acts in 80,817 publications by 50,070 authors as of Sept. 5th, 2017. Consistent unambiguous names are the tools on which biological research and conservation practices are built. As we pursue the goals of documenting and conserving biodiversity for which stable nomenclature is essential, we must do so without restricting the freedom of taxonomy.

96-3 WINTERS, GC*; BOSTWICK, CJ; WEBER, HE; KOHN, AB; MOROZ, LL; Univ. Florida Whitney Lab/Neuroscience, Transylvania Univ, KY; *gabrielle.winters@gmail.com*

Molecular organization of Octopus brains reveals insight into unique memory centers

Cephalopods exhibit behavioral flexibility that rivals that of many mammals. The Vertical Lobe circuit (VL), a structure unique to cephalopods containing memory circuitry, parallels mammalian analogues (hippocampus) in cell number and function, but has evolved independently in the molluscan lineage. We used integrative Next-gen sequencing and bioinformatics, followed by anatomical validation using in-situ hybridization, to identify the first molecular maps of signaling molecules in cephalopod memory circuitry. We constructed, sequenced and analyzed *Octopus* transcriptomes of 96 tissues (VL and other neuronal tissues and periphery). We compared these transcriptomes to the *Octopus* genome and our gastropod neural transcriptomes including *Aplysia californica*. We identified 16,194 transcripts in the VL (TPM >/=1) and found 4,139 (25.5%) appear to be cephalopod-specific. Although indicators for classical neurotransmitters were present in VL circuit transcriptomes they are far less abundant than secretory peptides. We used both targeted and unbiased bioinformatics to identify 141 distinct putative secretory molecules in *Octopus* nervous tissues, approximately 65% of which have not been described before in any species. We have systematically cloned and mapped expression of NPs, and have localized 27 NP to the components of the VL circuit. The diversity of secretory peptides reveals multiple morphologically distinct cell types in the LE neurons, previously thought to be homogenous. This expansion of novel signaling molecules in the VL circuit is likely a key feature of the unique memory systems of cephalopods, further implying extensive parallel evolution of cephalopod brains and memory circuits in particular.

P3-50 WINWARD, J.*; RAGAN, C.; JIMENEZ, A.G.; Colgate University, Purdue University Northwest; *jwinward@colgate.edu*
Cellular metabolic rates and oxidative stress profiles in primary fibroblast cells isolated from virgin females, moms, and male Sprague-Dawley rats.
Differences in reproductive strategies may dictate lifespans of organisms, as posited by the life-history theory. Animals that have higher investments in reproduction in terms of litter size and frequency of litters tend to have shorter lifespans. Accumulation of oxidative stress damage has been proposed to be a cost of reproduction and a possible mediator of life-histories among animals. In order to test the effect of reproduction on metabolism and oxidative stress of rats at the cell level, we grew primary dermal fibroblasts from Sprague-Dawley rats which invest heavily in reproduction and have the potential of having large litters frequently. Cells were isolated from virgin females, primiparous females, multiparous females and males. We measured basal oxygen consumption (OCR), proton leak, ATP production, spare respiratory capacity, coupling efficiency and glycolysis using a Seahorse XF96 oxygen flux analyzer. Additionally, we measured rates of RS (reactive species) production, reduced glutathione (GSH), mitochondrial content, and lipid peroxidation (LPO) damage to quantify oxidative stress. There were no significant differences in any OCR or glycolytic parameters across any of our groups. However, reproductive females had significantly lower rates of LPO damage as compared with virgin females and males, as well as nonsignificant decreases for GSH concentration. Decreases in LPO damage and GSH indicate that reproducing females use their antioxidant system in order to combat potential effects of increases in metabolic rate during reproduction. Our results suggest that reproduction may, in fact, have a protective effect in females.

P1-143 WITMER, LM*; PORTER, WR; CERIO, DG; NASSIF, JP; CAGGIANO, EG; GRIFFIN, CA; RIDGELY, RC; Ohio Univ.; *witmerL@ohio.edu*
spiceCT—Selectively Perfusable Iodine-based Contrast-Enhanced CT, a rapid alternative to diceCT for 3D visualization of vertebrate soft tissues
The treatment of vertebrate specimens with radio-opaque substances to enhance soft-tissue contrast in CT scans has revolutionized morphological analysis. DiceCT has produced spectacular results and involves immersing specimens in Lugol's iodine. A shortcoming of diceCT is that diffusion (the "d" in "diceCT") can take days, weeks, or months in large, intact, unskinned specimens. Moreover, long diffusion times can cause marked shrinkage. Alternatively, our team has developed spiceCT, which involves perfusing specimens with Lugol's iodine, yielding excellent results—literally within hours. The vascular system of thawed, unfixed, unskinned specimens (mostly birds thus far) is cannulated, and then hypertonic (2.5 or 5%) aqueous Lugol's iodine is injected with a syringe. The solution perfuses well, easily filling capillary beds. Perfusion can be visually monitored in key areas, as well as tactilely via syringe pressure. Staining is rapid, and specimens can be scanned immediately, yielding same-day results. There is no time for shrinkage. The absence of prior fixation shortens processing time and also opens new avenues for final storage in that the specimen can be fixed, refrozen, or even skeletonized. Perfusion rather than diffusion also allows targeting of tissues—selective perfusion (the "sp" of "spiceCT")—by injecting their vascular supply. One shortcoming of spiceCT is that iodine is too large to cross the blood-brain barrier (BBB), and thus the method is not currently useful for studying brain anatomy, although our team is exploring ways to overcome this problem. SpiceCT is intended to supplement, not replace, diceCT in the toolkit of morphologists.

82-6 WITTMAN, TN*; COX, RM; Univ. of Virginia; *tw9jj@virginia.edu*
Promiscuity and Parasites: Mating System Predicts the Survival Costs of Parasitism Across Taxa
Parasites are known to reduce survival, but the extent to which this cost varies between sexes is generally unknown. Males are often assumed to have greater parasite loads and suffer greater costs from parasitism, however, females also invest substantially in reproduction and may face similar costs. To test for a sex bias in the extent to which parasitism reduces survival we conducted a meta-analysis using studies that measured the survival costs of parasitism on males and females simultaneously, both vertebrate (n=18) and invertebrate (n=21) species were included. We also characterized each species with respect to mating system (Promiscuous, Polygynous, Monogamous) and sexual size dimorphism (male-biased, monomorphic, female-biased) to test whether these proxies for sexual and sex-specific selection predict variation in the extent to which males and females suffer survival costs of parasitism. Our results confirm that parasites are costly, with parasitized individuals facing a 3.2-fold increase in the risk of mortality, however, this increase did not differ by sex. Moreover, neither of the predictive variables we tested had a significant effect on the difference in costs between males and females. However, we found that promiscuous species faced higher survival costs of parasitism than monogamous and polygynous species. In addition, species with female-biased SSD faced greater survival costs then those with no bias or with a male-biased SSD. Males and females in promiscuous systems may each have steeper Bateman gradients than in monogamous and polygynous systems and thus may both benefit from increased investment in reproduction at the expense of survival.

132-1 WOLF, Z*; JUSUFI, A; VOGT, D; LAUDER, G; Harvard University; *zwolf.mlxvi@gmail.com*
Creating and exploring an active-swimming soft-robotic apparatus for studying fish locomotion
Last year we showed that by bilaterally attaching soft robotic actuators (pneunets) to a flexible passive foil, we could construct an active swimming model for fish locomotion called the ‘pneufish'. Pneunets consist of a series of connected, segmented chambers molded from Smooth-on Dragon Skin silicone that can be pressurized. When pressure is increased, each chamber expands and pushes against its neighboring chambers, resulting in a net lengthening and curvature of the pneunet. Attaching a pneunet to each side of a flexible foil ‘backbone' creates an actively controlled swimming fish model. We assembled pneufish and suspended them in a recirculating flow tank attached to an ATI 6-axis force-torque sensor. We measured thrust, lateral forces, and amplitude of trailing edge oscillation and investigated the swimming performance of the model at a variety of frequencies, flow speeds, foil stiffnesses, and air pressures. A brief exploration of the available parameter space revealed that the pneufish generated positive thrust and undulatory propulsion only at certain parameter combinations - namely, high activating air pressure and low undulatory frequency. An improved digital pressure regulatory system shows that the model can achieve realistic propulsion across a larger variety of parameter combinations. Changing the minimum pressure level in the pneunets does not significantly affect performance, but changing the amount and frequency of air injection into the pneunet does. Additionally, we have expanded the model from a simple two-pneunet apparatus (duo-pneufish) to a four-pneunet apparatus consisting of two consecutive pneunets on each side of the foil (quad-pneufish), and plan future experiments to evaluate the performance of this multi-segmented system that is more fish-like.

P3-65 WOLF, SE*; ROSVALL, KA; Indiana University; *wolfsae@indiana.edu*

How maternal stress affects juvenile telomere dynamics: an experimental test in tree swallows (Tachycineta bicolor)

Telomeres are conserved nucleotide sequences that protect genomic integrity and naturally shorten during DNA replication; therefore, telomeres are perhaps best known for their negative relationship with age, where higher rates of loss occur earlier in life during rapid growth. However, high variation in telomere length within age groups suggests that age alone cannot explain all variation in telomere dynamics. One possibility is that early life stressors may ‘program' later telomere dynamics and influence how animals cope with their environment. Here, we tested the hypothesis that maternally-experienced stress influences offspring telomere shortening during postnatal development. Specifically, we administered an immune challenge (i.e. lipopolysaccharide - LPS) to free-living female tree swallows (*Tachycineta bicolor*) early in the chick provisioning period and measured physiological and performance-related effects of this stressor on females and their chicks. We found that LPS injection led to declines in female nest visitation rates, resulting in significantly slower growth of chicks during the 24-48 hour period of female sickness; however, chicks of LPS-injected females experienced accelerated ‘catch-up' growth, resulting in no mass difference between treatments by 12 days of age. We also quantified the effects of these maternal immune challenges on chick telomere shortening, with the prediction that chicks experiencing compensatory growth suffer from accelerated telomere attrition and other performance-related costs. Our results explore the intergenerational effects of an immunological stressor on offspring growth and telomere dynamics and in doing so, will provide novel insights into the causes of variation in telomere length.

P2-138 WOLF, CJ*; SASSER, KT; SENNER, NR; CHEVIRON, ZA; Univ. of Montana; *colejwolf@gmail.com*

Phylogeography of Peromyscus maniculatus across the Colorado Front Range

Species distributed across heterogeneous environments may adapt to local conditions as a result of differing selection pressures. This process can lead to adaptive divergence, where populations are subdivided based on the different environments they inhabit. High levels of gene flow have the potential to homogenize genetic variation across the landscape, particularly if migration rates are high and the strength of selection for locally adapted loci is low. In this case gene flow is only limited by dispersal, and population structure will arise as a result of geographic distance. However, local adaptation can still occur in the face of gene flow if selection for a local optimum is sufficiently strong. High altitude environments impose strong selective pressures on homeothermic endotherms, as the dual stressors of cold temperatures and hypobaric hypoxia constrain their ability to maintain a stable body temperature via aerobic thermogenesis. The deer mouse (*Peromyscus maniculatus*) is continuously distributed from sea level to over 4,300 meters in elevation, so this species is an ideal system to investigate the interaction between gene flow and local adaptation to high altitude. We sampled thirty deer mouse populations along seven transects spanning a 3200-meter elevational gradient in the Colorado Front Range in the summers of 2016 and 2017. We then used restriction-site associated DNA (RAD) sequencing to generate a dataset of thousands of single nucleotide polymorphisms. The program STRUCTURE and R-package BEDASSLE were employed to examine population structure and test the relative strength of geographic versus environmental distance on population structure.

31-5 WOLFF, GH*; LAHONDèRE, C; VINAUGER, C; RIFFELL, JA; Univ. of Washington; *gabwolff@uw.edu*

Selective Memory: Mosquitoes Learn Salient Olfactory Cues Associated with Preferred Hosts

With over 3500 species, mosquitoes have evolved a wide range of host preferences, feeding on vertebrates, invertebrates, plant fluids and even ant regurgitation. Mosquitoes can use olfactory information from feeding experiences to learn positive or negative associations with certain hosts, but not all odors can be learned by each species. To understand the neural basis of differential learning across species with various host preferences, we used an integrative approach of combining behavioral assays with neuroanatomical studies to understand the neural underpinnings of these behaviors. To test the hypothesis that mosquitoes only learn the most salient odors associated with their preferred host, we trained mosquitoes from four species that prefer either human hosts, bird hosts, or purely nectar feeding in a classical conditioning paradigm. *Aedes aegypti* and *Anopheles stephensi* (prefer humans) learned vertebrate host odors, but not flower odor; *Toxorhynchites amboinensis* (nectar feeder) only learned a flower odor; and *Culex quinquefasciatus* did not exhibit learning behavior in this study. We next examined patterns of dopaminergic innervation in central brain pathways mediating olfactory learning such as the antennal lobes and mushroom bodies. Staining patterns suggest a relationship between differential abilities of mosquitoes to learn salient host odors and differential patterns of dopaminergic neuromodulation in olfactory learning circuits. These results contribute to our understanding of mosquito learning, which can modify vector-host transmission of diseases and more broadly to our understanding of dopaminergic modulation of olfactory learning circuitry in insects.

P2-251 WOLFORD , D.M.*; DAVIS, J.E.; Radford University ; *awolford5@radford.edu*

Studying Behavioral Interactions between Various Species of Ants and an Entomopathogenic Fungus, Ophiocordyceps unilateralis

Ants communicate with their fellow colony members through the use of pheromones. Not only do ants communicate through scent, but they can also distinguish whether another ant is "friend or foe" by the number of hydrocarbons on the cuticle. Studies have also shown that ants can identify other ants of the same species that are infected with the cordyceps fungus. In our study, we collected various deceased ants of various species infected with the entomopathogenic fungi, *Ophiocordyceps unilateralis*, and studied how healthy ants of the same and different species responded while near the infected host. For each species, we placed them into a testing chamber and recorded the interaction between the healthy ant and the cordyceps infected ant for two minutes. Similar studies were conducted using non-parasitic fungi and deceased, non-infected ants. Video interactions were then analyzed with Noldus Ethovision XT software. While it was predicted that ants would stay away from the cordyceps infected host, some exhibited the opposite behavior and explored it.

P1-97 WOLINSKI, CJ*; WATSON, CM; Midwestern State University; *cierajayden@gmail.com*

Thermal physiology of the giant Hispaniolan galliwasp (Celestus warreni)

The direct and indirect effects of deforestation, coupled with general anthropogenic climate change, are increasing global temperatures at an alarming rate. It is important, therefore to understand the physiological response of organisms to different temperatures in order to predict future effects of an elevated thermal environment on their populations. Among the organisms experiencing the acute effects of deforestation is the giant Hispaniolan galliwasp, especially among populations in Haiti. This lizard is classified as vulnerable by the IUCN because of habitat destruction and urbanization. Here we quantify metabolic rate and Q_{10} at four ecologically-relevant temperatures and establish optimal temperatures using maximum locomotor performance. Our research shows that this species may be especially vulnerable due to their relatively low thermal optima and metabolic response to higher temperatures.

132-7 WONDERLY, W.R.*; DEMARTINI, D.G.; MONNIER, C.A.; WAITE, J.H.; University of California, Santa Barbara; *wwonderly@chem.ucsb.edu*

Between the Melanin Nanosheets with a Naked Polychaete

Nature utilizes a variety of chemistries in order to generate hardened materials. One curious example is *Glycera dibranchiata, a burrowing intertidal sandworm that utilizes four black, venom-injecting jaws to grasp and attack its prey. The composition of these jaws has been shown to be approximately 50% protein, 10% copper (in mineralized and ionic form), and, surprisingly, 40% melanin. However, because these jaws are highly sclerotized, the only previous characterization of the protein component has been amino acid analysis, which has indicated a striking composition of >50% glycine and >30% histidine. In this study we have utilized next generation sequencing to identify a 23kDa protein fitting this composition. We show that this protein binds a large amount of copper (20 Cu atoms per protein) with high affinity, and that the copper-bound protein complex exhibits catechol oxidase activity toward 3,4-dihydroxy-L-phenylalanine. Finally, using scanning electron microscopy and atomic force microscopy we have identified the product of this catalysis to be synthetic melanin sheets with a thickness of ~45 Å with a very large surface area. Understanding the multifunctionality of this protein (metal binding, catalysis, and scaffolding) will allow unprecedented control over the morphology of a biopolymer that is notoriously complex and opens the door to many engineering applications.*

P3-223 WONG, Y.Y.*; LE, P.H.; SENATORE, A.; University of Toronto Mississauga; *adriano.senatore@utoronto.ca*

Transcriptome Analysis of Trichoplax adhaerens Provides Insight into the Evolution of Synaptic and Paracrine Cell-cell Signaling

Trichoplax adhaerens is an early-diverging animal that, despite lacking synaptically connected neurons and muscle, is able to carry out motile behavior such as feeding. Our lab has produced a high quality *T. adhaerens* transcriptome, in which a majority of assembled gene sequences are complete (>85% bear both start and stop codons), with 2,483 novel genes previously missed in the genome sequencing effort. A major objective of this project is to identify *T. adhaerens* genes homologous to human/vertebrate nervous system genes (e.g. those involved in neuronal signaling, neuromodulation, and disease). Using various *in silico* prediction algorithms we have identified numerous genes including neuropeptides, GPCRs, ligand-gated ion channels, and synaptic scaffolding proteins. Using our data, we are conducting a phylogenetic analysis of key synaptic scaffolding proteins, and evaluating expansion/loss of PDZ and SH3 protein scaffolding domains, to gain insights into evolution of the synapse. Our work provides a foundation for molecular studies centered on understanding the evolution of neuromodulatory and synaptic cell-cell signaling.

P1-141 WOOD, HM; FLYNN, BI*; Smithsonian Institution, Washington, DC, University of Texas, Austin ; *brianna.flynn@utexas.edu*

You Are How You Eat: Chelicerae Orientation and the Diversification of Spiders (Arachnida: Araneae)

Spider chelicerae, which are functionally equivalent to jaws, are a crucial component to spider biology and successful prey capture. Not much is known about the diversity of this trait in spiders, or how the chelicerae have evolved to adapt to different ecological pressures. In this study, we test how the various shapes and orientations of the chelicerae have diversified across the major spider lineages. Our hypothesis is that hunter spiders, because of their reliance on cheliceral performance compared to those that use a snare to capture their prey, have experienced an increased rate of cheliceral trait evolution. We measured seven morphological traits of the cephalothorax for 84 representative spider species. These values were then compiled in a matrix, with which we performed a phylogenetically corrected Principle Component Analysis. We used the first and second PC values to construct a plot visualizing the cheliceral morphospace across spiders. The rate of cheliceral trait evolution was then determined via BAMM analysis, using the three PC values with the highest eigenvalues and our size data. Our preliminary data shows that ground hunting spiders show an increased rate of trait evolution relative to orb weaving and web building spiders. This suggests that the evolution of a hunter lifestyle promoted an adaptive radiation in cheliceral trait morphology.

80-5 WOOD, T.C.*; KELLEY, R.E.; MOORE, P.A.; Bowling Green State University, University of Michigan; *tcwood@bgsu.edu*

Non-consumptive Effects as Drivers of Physiological Change in a Tri-trophic Interaction

Non-consumptive effects (NCEs) occur when stimuli from predators illicit a behavioral, physiological, or morphological response in prey species. Prey often alter their foraging habits in response to NCEs, which can initiate a trophic cascade that impacts a third trophic level, commonly a primary producer. This model is well studied in terms of abundance and behavior of the constituent species. However, the mechanisms underlying the physiological response of primary producers to changes in herbivory pressure driven by NCEs remain understudied. We hypothesized that the presence of predators in the environment would cause an observable reduction in foraging behavior of prey species. The resultant drop in herbivory pressure would then be followed by a decrease in the amount of defensive chemicals found in plant tissues. We tested this hypothesis using a new tri-trophic model at the Stream Research Facility at the University of Michigan Biological Station. Our model consisted of *Micropterus salmoides* to provide a predatory stimulus, *Orconectes rusticus* as the herbivorous prey, and three plants *Myriophyllum sibericum*, *Elodea canadensis*, & *Chara* macroalgae as the responsive primary producers. A two by two fully factorial experiment was performed using eight flow through stream mesocosms fed with strained river water that ran for 48hrs per trial cycle. Macrophytes were present in all trials, while the presence of bass odor, and presence of crayfish were factors. A mixed effects modeling approach in R was used to analyze our data. We found that crayfish consumed more plant tissue when predator odor was present, and plants gained more weight in predator odor positive, herbivore free trials.

61-3 WOOD, HM*; PARKINSON, DY; GRISWOLD, CE; GILLESPIE, RG; ELIAS, DO; Smithsonian Institution, Lawrence Berkeley National Laboratory, California Academy of Sciences, University of California, Berkeley; *woodhannahmarie@gmail.com*

Repeated Evolution of Power-Amplified Predatory Strikes in Trap-Jaw Spiders

Small animals possess intriguing morphological and behavioral traits that allow them to capture prey, including innovative structural mechanisms that produce ballistic movements by amplifying power. Power amplification occurs when an organism produces a relatively high power output by releasing slowly stored energy almost instantaneously, resulting in movements that surpass the maximal power output of muscles. For example, trap-jaw, power-amplified mechanisms have been described for several ant genera, which have evolved some of the fastest known movements in the animal kingdom. However, power-amplified predatory strikes were not previously known in one of the largest animal classes, the arachnids. Mecysmaucheniidae spiders, which occur only in New Zealand and southern South America, are tiny, cryptic, ground-dwelling spiders that rely on hunting rather than web-building to capture prey. Analysis of high-speed video revealed that power-amplified mechanisms occur in some mecysmaucheniid species, with the fastest species being two orders of magnitude faster than the slowest species. Molecular phylogenetic analysis revealed that power-amplified cheliceral strikes have evolved four times independently within the family. Furthermore, we identified morphological innovations that may have set the stage for the parallel evolution of ballistic predatory strikes.

P1-3 WORD, KR*; DUCKLES, BM; BROOKS, PT; JOHNSON, LK; BROWN, CT; UC Davis, Portland State University; *krlizars@ucdavis.edu*

Perspectives from an intensive bioinformatics training workshop with a heterogeneous learner population: success takes many different forms

Learners at ANGUS, a 2-week summer workshop on analysis of next-generation sequencing, range from undergraduate to faculty, may be novice, self-taught, or pre-trained, and hail from multiple countries. They reflect a full cross section of biological disciplines. Feedback for this course has been overwhelmingly positive in its 8-year history, but the extent to which this reflects effective instruction is unclear. It is also not clear whether all learners are served equally well. We distributed surveys, conducted interviews and classroom observations, and collected in-class feedback from learners. We also surveyed the volunteer instructors and helpers. These data suggest that satisfaction is based on different criteria for learners of different backgrounds. We note interesting variation in the ways in which learners conceptualize community as a resource for future support. Further perspectives on the value of participation to instructors and helpers, as well as support and challenges specific to novice learners and non-native English speakers will be presented. Ongoing retrospective study and plans for future intensive and sustainable assessment of this program will also be outlined. While this work arises out of an unusual setting - training biologists of all stripes in computational skills - the challenges faced in assessing this program are ubiquitous. The heterogeneity of this learner population and the flexibility of the workshop setting offer a unique opportunity to think expansively about how education creates value for diverse participants and the institutions that thrive on their work.

66-6 WRIGHT, CM*; TIBBETTS, EA; PRUITT, JN; University of California, Santa Barbara, University of Michigan; *colinuniversity@gmail.com*

Exploring the effects of queen personality on fitness and colony success in paper wasps

The founding individuals of a new group or lineage are uniquely poised to have long-lasting effects on their descendants. Here we explore how the behavioural traits of new paper wasp queens influence their task allocation strategies and the downstream collective behavior of their colonies. We then test to see whether these personality traits matter in the field by tracking the success of queens of known behavioral type and size over an entire season. From these data, we are able to determine how personality and morphology influences colony growth and survival in the wild.

19-1 WROBEL, ER*; KHAN, NY; CURRY, JE; MENDONCA, MT; NAVARA, KJ; University of Georgia, Auburn University; *ewrobel@uga.edu*

An examination of current practices of testosterone administration: comparing the effects of testosterone versus testosterone propionate implants in the hen

Physiologists often use testosterone propionate (TP) to generate long-term elevations of testosterone (T) because TP has a much longer half-life within the body than T and thus, may exert stronger, more long-lasting effects. Our work, however, indicates that T and TP cannot necessarily be used interchangeably when conducting studies aiming to test the impacts of T on animal physiology and behavior. We implanted laying hens with silastic implants (1/4 inch, ½ inch, and 1 inch long) containing either TP or T. Even the smallest implant size containing TP resulted in complete disruption of egg-laying while the same size implant containing T did not. Larger implant sizes containing TP caused complete ovarian regression within days of implantation and masculinization of behaviors and comb sizes for months after implantation. Our work suggests that while many studies use TP in place of T for studies on animal physiology and behavior, we need to know more about how it interacts with receptors, how long it takes to break down in the body, and how it may impact wildlife in the long-term, particularly in cases where reproductive output is not being measured and thus cannot act as an indicator of the potential detrimental effects associated with TP.

P2-113 WYND, BM*; DEMAR, DG; WILSON, GP; Virginia Tech, Univ. of Wash.; *bmwynd@vt.edu*

Diversity of Chondrichthyes through the uppermost Cretaceous Hell Creek Formation of Garfield County, Montana, with implications for the Cretaceous-Paleogene mass extinction in freshwater environments

The Cretaceous-Paleogene (K-Pg) mass extinction is a well-studied mass extinction event, but vertebrate diversity patterns surrounding the event are not fully understood. Two main competing hypotheses are: (1) a sudden and rapid loss of many species at the K-Pg boundary (ca. 66 Ma) caused by a Bolide impact (Chicxulub); and (2) vertebrate biodiversity declines prior to and at the K-Pg boundary due to multiple factors (e.g., sea levels, volcanism, bolide impact). We examine biodiversity of Chondrichthyes from freshwater deposits of the Hell Creek Formation (HC), Garfield County, Montana. We analyze diversity dynamics using 426 fossil teeth from seven vertebrate microfossil localities stratigraphically distributed throughout the HC. Using raw taxonomic, standing, subsampled analytic rarefied, and shareholder quorum subsampling (SQS) richnesses, our study shows that raw richness increased from six species in the lower third of the HC to a peak of eight in the middle third followed by a decline in the upper third (five species). This stepwise decline in diversity is mimicked in SQS and standing richnesses, also. Our estimates include the occurrences of four new shark species based on morphologically distinct teeth. We also report on the first sand tiger shark from the HC, indicating a freshwater incursion by this, otherwise, marine taxon. This decline in diversity more closely resembles stepwise patterns shown for amphibians (aquatic) than sudden extinction patterns for mammals or lizards (terrestrial), indicating that the aquatic vertebrates from the HC likely had multiple causal factors affecting their biodiversity, such as proximity of the Western Interior Seaway.

P1-128 XU, L*; HE, L; SAITO, A; WANG, V; CHEN, T; KOYAMA, T; SUZUKI, Y; XU, Lily; Wellesley College, Gulbenkian Institute ; *lxu3@wellesley.edu*

Physiological adaptation to distinct feeding strategies in Drosophila and Manduca larvae

Body size is an important life history characteristic that determines fitness. The final body size is determined in part by the timing of attainment of two key body size checkpoints, the critical weight (CW) and the minimum viable weight (MVW). In *Drosophila melanogaster*, these two checkpoints are indistinguishable and refer to the minimum weight necessary to metamorphose on time. Manipulating the PG in *Drosophila* has indicated that the MVW/CW is also the point at which endoreplication and ecdysteroidogenesis in the PG become nutrient independent (Ohhara et al, 2017). In contrast, in *Manduca sexta*, unlike *Drosophila*, the CW and MVW are distinct checkpoints. In this study, the effects of starvation and hypoxia on *Manduca* PG size were examined to see how they affected gland growth. In addition, the expression of two P450 enzymes involved in ecdysone biosynthesis, *phantom* (*phm*) and *disembodied* (*dib*), along with a JH response gene, *kruppel homolog* (*kr-h1*), were analyzed at different larval weights. Our preliminary data suggest that unlike in *Drosophila*, ecdysteroidogenesis in *Manduca* is nutrient dependent throughout much of larval development, including post MVW/CW. Our findings indicate that the physiological regulation of growth is highly adapted to the feeding ecology of insect species.

132-2 XU, NW*; DABIRI, JO; Stanford University; *nicolexu@stanford.edu*

External Control of Jellyfish Swimming and Validation of Turning Kinematics

Aurelia aurita is an oblate species of jellyfish composed of a flexible bell and subumbrellar coronal muscle that contracts to provide motive force. Because *A. aurita* is a simple and energy-efficient model organism capable of surviving in a broad range of environments, the external control of its locomotion can potentially enable more efficient aquatic vehicles for ocean monitoring. However, traditional robotics requires more complicated manufacturing and is constrained by power consumption; by implementing a portable swim controller on a biological system, we can simplify the robotic design and take advantage of a naturally existing scaffold and neuromuscular system. We achieve external control of swimming by using a compact wireless system of microelectronics and 3D-printed housing attached to the bell, with electrodes inserted into the bell margin for direct muscle stimulation. To validate this system, we obtain the bell kinematics using accelerometer data in conjunction with 3D particle tracking velocimetry by injecting biocompatible elastomer tags along the bell margin, illuminating the setup with ultraviolet light, and tracking particles using multiple camera views. Future work will connect these controls and kinematics to existing flow measurements to understand animal-fluid interactions.

P3-155 YACOUB, L*; REAGAN, E; MUñOZ-GARCIA, A; The Ohio State University at Mansfield; *yacoub.17@osu.edu*

The link between cellular metabolism and resource allocation to reproduction: phenotypic plasticity of organ size

Patterns of energy and resource allocation to maintenance, growth and reproduction are related to lifetime reproductive output. One mechanism that might drive allocation of resources is phenotypic plasticity of organ size. Animals can increase or decrease the size of metabolically active organs in response to certain environmental conditions; that might have consequences in overall expenditure and allocation of energy. We studied phenotypic plasticity of organ size in females of *Diploptera punctata*, a viviparous cockroach. Female *D. punctata* give birth 9-12 nymphs after a gestational period of 55-60 days. We used four groups of females: (1) pregnant females at day 55 fed with a high quality (HQ) diet, (2) pregnant females at day 55 fed with a low quality (LQ) diet, (3) non-pregnant females in which we switched diets from LQ to HQ, then back to LQ in periods of 30 days, and (4) non-pregnant females in which we switched diets from HQ to LQ then to HQ again in periods of 30 days. We measured metabolic rate (MR), and mass of digestive tract, abdominal organs, embryos in the pregnant females, and carcass. We found a positive relationship between gut mass and MR, and a negative association between the mass of abdominal organs and MR. There was a trade-off between gut mass and abdominal organ mass, and gut mass and reproductive output. Females acclimated to LQ adjusted their physiological traits in a manner dependent on the previous acclimation event, but when food availability was high in the first event, there was no relationship between changes in MR and diet. We conclude that changes in organ mass in response to environmental conditions determines complex patterns of allocation of resources to reproduction in *D. punctata*.

P2-275 YANG, Y*; SERVEDIO, M; RICHARDS-ZAWACKI, CL; Univ. of Pittsburgh, Univ. of North Carolina, Chapel Hill; *yusan.yang8@gmail.com*

Learned color bias in a polymorphic poison frog: implications for trait evolution and speciation

Sexual selection can drive rapid divergence in mating traits and behaviors, which may facilitate speciation by creating behavioral isolation among phenotypic variants. Behavioral responses to the diverged trait can limit gene flow among young lineages; however, the evolutionary outcomes depend profoundly on whether the behaviors are genetically inherited or learned. Here, we tested the hypothesis that color-mediated behaviors in the polymorphic poison frog *Oophaga pumilio* are learned, and explored the ability of such learned behavior to drive color evolution and speciation using mathematical modeling. Male and female *O. pumilo*, in general, respond more strongly to their own color morphs than to different color variants in wild populations. We showed in a cross-fostering lab experiment that these color-mediated behaviors are learned through interactions with the parents, especially the mother, perhaps during egg provisioning at the tadpole stage (i.e. maternal imprinting). Deterministic simulations in diploid population genetics models revealed dual roles in both learned female preference and learned male aggression bias. Stronger female preferences result in higher trait-preference linkage disequilibrium (a proxy of degree of reproductive isolation), but tend to lead to loss of polymorphism via positive-frequency dependent selection. Male aggression bias can generate negative-frequency dependent selection that keeps polymorphism from going to fixation, but result in lower trait-preference linkage disequilibrium when bias strength is asymmetric between phenotypes. Given this, the divergent color-mediated behaviors in *O. pumilio* thus appear to serve a more complex role in speciation than previous studies have assumed.

128-8 YAP, KN*; POWERS, DR; TSAI, OH; WILLIAMS, TD; Simon Fraser University, George Fox University; *knyap@sfu.ca*

Do physiological adjustments to high foraging effort affect reproduction?

One of the key determinants of reproductive success in birds is the quality of parental care and, thus, increased foraging effort associated with rearing chicks. However, there appears to be large individual variation in parental effort, suggesting that individuals vary in the cost they pay for "working hard". Additionally, costs of activity can often be deferred from one life-history stage to a later stage (i.e. carry-over effects). Although some studies have found that increased workload negatively affects reproduction and survival, little is known about the physiological mechanisms underlying carryover costs associated with high workload. We experimentally manipulated foraging effort in captive zebra finches (*Taeniopygia guttata*) to examine how high workload affects energy expenditure, oxidative stress and reproductive output. During phase 1 of the experiment, birds were subjected to either, a) a high foraging cost treatment (HF; feeders suspended from the cage roof with no perches) or b) control foraging conditions (CTRL) for 2 weeks, after which all birds were paired for breeding under common-garden CTRL conditions. During phase 2 of the experiment, HF birds were again housed and trained in the HF treatment and were then paired for breeding while being kept in the same HF condition. CTRL birds were given regular feeders throughout the experiment. Blood samples were collected at multiple time points to assess daily energy expenditure (using doubly-labeled water) and oxidative stress. Breeding propensity, egg and clutch size, and breeding productivity were assessed for both reproductive attempts. We predicted that HF birds would have lower reproductive output and have higher daily energy expenditure and oxidative stress than CTRL birds.

123-6 YARBROUGH, AM*; MARTIN, KLM; Pepperdine University; *alorayarbs@gmail.com*

Effects of Increased Air and Water Temperatures on the Embryonic Development of the California Grunion

As the earth's atmosphere becomes warmer in response to global climate change, more organisms are being affected at varying stages of their life history. The California Grunion, *Leuresthes tenuis* is a beach spawning teleost that is endemic to the Pacific Coast of North America from Tomales Bay, CA to Punta Abreojos, Mexico. *L. tenuis* may be uniquely affected by rising temperatures due to its unusual embryonic development occurring in a terrestrial environment rather than a marine one. To examine the effects of embryonic development of *L. tenuis* under temperature stress, I examined the effects of exposure to high temperatures for only a portion of the day coupled with a rest period of a lower temperature overnight. Little has been done to compare the incubation of *L. tenuis* in water versus air, so I also describe the developmental differences observed between eggs incubated in sand versus seawater. Eggs were incubated in either sand or water in three temperature conditions: constant 20°C, alternating 30°C for eight hours and 20°C for sixteen hours resulting in a mean temperature of ~23°C, and constant 30°C. The eggs were examined under a microscope daily to monitor developmental progress. Daily hatching success testing began at 5 days post fertilization and hatchling length was sampled. The eggs incubated in water showed more frequent deformities, slower embryonic development, lower hatching success, and shorter hatchling length than those incubated in sand across all temperature treatments. Future studies should focus on the mechanisms that cause the developmental deficiencies in eggs incubated in water.

22-7 YARGER, AM*; FOX, JL; Case Western Reserve University; *amy9@case.edu*

Rapidly Adapting Mechanosensors Differentiate Between External and Self Motion

The ability of dipteran insects (flies) to perform complex acrobatic maneuvers while maintaining stability in flight is due in part to specialized sensory organs called halteres. Halteres are modified hind-wings that oscillate in antiphase with the fore-wings during flight and detect inertial forces produced by body rotations (Nalbach 1993). The sensory encoding of haltere primary afferent neurons has been described using motors to oscillate the haltere. Yet, it is not known if responses to artificial motions are predictive of actual haltere sensory input during active behavior. By recording the activity of individual primary afferents in the haltere nerve during self-generated and externally-imposed haltere oscillations, we demonstrated that haltere mechanosensory neurons are more sensitive to imposed haltere movements than to actively-generated motion. By cutting the nerve and observing the same results, we showed that the change in sensitivity is due to a difference in activation of the sensory structures at the base of the halteres. Because there can be no neural feedback when the nerve is cut, the observed phenomenon is likely a function of the haltere's movements, rather than a neuromodulatory effect. We were also able to decrease the activation threshold by oscillating the haltere anterior to its natural plane. The phase locking of individual neurons remained highly precise regardless of the plane of oscillation, however the phase relationship between the haltere motion and the primary afferents' activity varied substantially. These data demonstrate that haltere primary afferent activation is highly sensitive to lateral displacement. Body rotations that occur during locomotor behaviors cause similar displacements, which suggests that body rotations may be encoded by activation threshold and phasing of primary afferents.

P3-209 YASUMASU, S*; SANO, K; NAGASAWA, T; KAWAGUCHI, M; Sophia Univ., Japan, Josai Univ., Japan, Jikei Univ., Japan; *s-yasuma@sophia.ac.jp*

Co-evolution of fish hatching enzyme and its substrate

Two evolutionary events in the egg envelope system affected the egg envelope digestion system of the hatching enzyme(s). The first event was the acquisition of the egg envelope hardening mechanism mediated by transglutaminase that occurred before the divergence of Teleostei fish, resulting in the acquisition of a toughened hard egg envelope. At this time, a switch in the substrate of the hatching enzyme occurred; the amphibian and sturgeon hatching enzymes selectively cleaved one of five egg envelope proteins, ZPAX, while Teleostei hatching enzymes cleaved the repeated sequences at the N-terminal regions of ZPB and ZPC, where most of the cross-links formed by transglutaminase were located. The second event was the acquisition of liver-synthesized ZP proteins, which occurred in the common ancestor of the Otocephala and Euteleostei. The ZP proteins in fish were originally synthesized in the ovary. The ZP-synthesizing proteins in the liver conferred the ability to develop a thick and protective egg envelope. Around that time, duplication of the gene encoding hatching enzyme occurred. Consequently, the fishes in the Otocephala and Euteleostei possess two types of hatching enzymes. In the Euteleostei, the two enzymes have developed into an efficient egg envelope digestion system that completely solubilizes the egg envelope; one duplicate has maintained the ancestral activity to swell and soften the egg envelope, and the other has acquired a new function to solubilize the swollen egg envelope. However, this type of efficient egg envelope digestion system did not develop in the Otocephala. One duplicate was lost in the Otophysi, and the liver-expressing ZP genes were also lost. Therefore, the evolutionary process of the egg envelope digestion system corresponds well with that of the egg envelope, suggesting co-evolution between these two systems.

P1-163 YEE, AK*; PERNET, B; California State University Long Beach; *alisonkyee@gmail.com*

Do larval settlement preferences determine local distribution patterns of the serpulid annelid Ficopomatus enigmaticus?

The serpulid *Ficopomatus enigmaticus*, likely a native of Australia, has established populations on every continent except Antarctica. Invasive populations of this species often show two striking distributional patterns: individuals are found in dense aggregations (reefs), in low salinity habitats. A process that may be important in establishing both patterns is the expression of settlement preferences by larvae. To test the hypothesis that larvae of *F. enigmaticus* settle preferentially on conspecific adults, contributing to reef formation, we conducted two experiments. First, larvae were exposed to biofilmed tubes of conspecific adults or to biofilmed shell or tube of two other species. Settlement was significantly higher on conspecific tubes compared to other substrates. Second, larvae were exposed to various substrates in clean seawater or in seawater in which adult worms had been held. Adult effluent had no effect on larval settlement. Larval responses to cues associated with the tubes of conspecifics may thus be one factor important in reef formation. To test the hypothesis that larvae settle most readily in low salinities, we examined larval settlement in response to adult tubes or IBMX (a pharmacological inducer) in seawater adjusted to 5, 20, or 34 psu. Settlement was high at all salinities tested in both adult tube and IBMX treatments, suggesting that larval responses to salinity are not important in determining the local distribution of *F. enigmaticus*. Future work should test alternative hypotheses to explain the observed distribution of adults with respect to salinity, for example that juveniles and adults are excluded from full-strength seawater habitats by competition from fully marine species.

93-4 YEGIAN, AK*; CASTILLO, ER; MCCABE, CM; Harvard University, Hunter College, CUNY, Duke University; *ayegian@fas.harvard.edu*

Are primates low energy? Testing the heat dissipation hypothesis for mammalian field metabolic rate scaling

Primate field metabolic rate (FMR) is low compared to non-primate eutherian mammals, with primates using less energy than expected for their body masses. The prevailing hypothesis is that lower-than-expected primate FMR reflects a metabolic adaptation for a low-throughput life history strategy. We propose an alternative hypothesis: that high ambient temperatures constrain primate FMR in a similar manner to other mammals that inhabit high ambient temperature environments . To test this hypothesis, we used a simple thermodynamic model for FMR similar to Speakman and Krol (2010). We predicted that FMR would scale to body mass (M_B) to the same exponent as surface area (A_S) and that remaining FMR variation would negatively correlate with mean ambient temperature (T_a). We tested the predictions using FMR, A_S, and T_a data from the literature and also tested the relationships between basal metabolic rate (BMR) with M_B and T_a. Both phylogenetically-informed and uninformed regressions produced the same results: FMR, BMR, and A_S all scale to M_B with the same general exponent of 0.70-0.72. As predicted, residual FMR variation showed a negative relationship with T_a. After accounting for M_B and T_a, primate FMR fit the general mammal prediction. Interestingly, residual BMR variation also had a negative relationship with T_a, which we interpret as a mechanism for maintaining metabolic scope (FMR/BMR) in the face of decreased FMR in warm environments.

S11-5 YEUNG, NW*; HAYES, KA; Bernice Pauahi Bishop Museum, Honolulu, HI, Howard University, Washington DC; *nyeung@hawaii.edu*

Extinction of the hyperdiverse Hawaiian land snail fauna: What remains and what are we doing to save it?

Plants and animals are under threat of extinction, primarily from human-mediated impacts to the planet. Despite insects, molluscs and other invertebrates comprising the clear majority of animal diversity, news headlines primarily feature stories of vertebrate extinctions. While nearly all mammal and bird species have been assessed for conservation by the IUCN, compared to less than 5% of molluscs, extinctions of the latter outnumber those for all vertebrates combined. This taxonomic bias is impeding conservation and hampering fundamental research, leaving glaring gaps in our knowledge of living animal groups, especially those most impacted by extinction. The loss of many of the 6000+ mostly endemic Pacific Island land snails is a grim reminder of the enormity of the extinction crisis that shows no signs of waning. The Hawaiian Islands support a spectacular radiation of land snails, with 750+ species and possibly 300 more undescribed. Yet, gaps in our knowledge of their systematics, biogeography and ecology hamper conservation efforts, and like most of the fauna throughout the Pacific islands, Hawaiian land snails are being lost quickly. Extinction estimates are as high as 95% and 10% per decade for some families. Although a considerable portion of this evolutionary legacy has already been lost, there are still at least 150 species, including undescribed taxa, that can be saved. To preserve these remaining species, we have started providing an updated systematic assessment of extant species and developed outreach programs that have changed public and conservation perceptions of snails. Continued improvements in our understanding and appreciation of these crucial ecosystem components may hopefully allow us to save these jewels of the Pacific.

P3-213 YORK, JM*; IMANI, S; ZAKON, HH; University of Texas at Austin; *juliayork@utexas.edu*

Tetramerization and sequence evolution of potassium channels of weakly electric fishes

Weakly electric fishes use electric signals produced in the muscle-derived electric organs for social communication and to sense their environment. Some species generate brief electric pulses lasting only a few hundred microseconds. Generation of these brief electric pulses is enabled by a potassium channel (Kcna7a) which is expressed only in the electric organ. Kcna7a evolved by duplication of an ancestral gene (Kcna7) that is widely expressed in muscle; expression of the other duplicate gene, Kcna7b, remains in the muscle. The electric organ Kcna7a channel has evolved rapidly to open quickly and at much more negative potentials than the Kcna7b channel, thereby allowing brief electric discharges. The sequences also reveal amino acid substitutions in the tetramerization domain of Kcna7a channel, but which came first: localization of protein expression or an inability to tetramerize? Could loss of tetramerization between these channel subunits have enabled the rapid sequence evolution of Kcna7a? To investigate this, we expressed variable ratios of Kcna7a and Kcna7b in heterologous cells by injecting mixes of mRNA and measuring the electrophysiological properties of these channels. We found that, despite sequence variability, these channels likely are able to tetramerize. This suggests that their rapid evolution was probably enabled by expression localization or that ability to tetramerize may not constrain evolution of gene duplicates.

P1-16 YOSHIDA, KT*; UYANIK, I; FORTUNE, ES; SUTTON, EE; COWAN, NJ; Johns Hopkins University, New Jersey Institute of Technology; *kyoshida@college.harvard.edu*

A new experimental system to test how the brain learns novel locomotion dynamics

Neural systems mediate robust sensory processing and adaptive feedback for locomotor control in animals. We developed a method to investigate adaptive responses to changes in locomotion dynamics in the glass-knifefish, *Eigenmannia virescens*. These fish perform a refuge-tracking task in which a refuge is moved by a precision motor system. In previous studies, we used this system to move the refuge sinusoidally at frequencies between 0.01 and 2 Hz for open-loop system identification of the fish tracking response. Here we developed a control system that allows us to generate dynamic movement of the refuge in relation to the fish's motion (tracked in real time from a live video feed). In this way, we alter the sensory consequences, via an experimentally determined transfer function, of the fish's own movement in a closed-loop paradigm. This dynamic feedback can be added to sinusoidal input signals to enable system identification while the fish is experiencing experimentally modified locomotion dynamics. Our hypothesis is that changes in locomotor dynamics will trigger adaptive responses in the fish's tracking performance. Further, we expect to observe a post-adaptation period, where the fish regains its original controller after the novel dynamics are removed. Preliminary results with sum-of-sines system identification support our hypothesis by exhibiting a decrease in fish's gain in response to some frequency bands and recovering the gain when the "novel locomotion dynamics" are removed. The data suggests that we can trigger and monitor adaptation and post-adaptation responses of a fish by using closed-loop feedback control system.

P2-139 YOU MAK, KT*; JUHL, AR; MAK, Kayley; Barnard College of Columbia University, Lamont-Doherty Earth Observatory of Columbia University; *kty2104@barnard.edu*

Effects of crude oil on the balance of autotrophy and heterotrophy in the Hudson River Estuary

Oxygen concentrations in estuarine water columns result from the balance of autotrophic and heterotrophic processes. Contamination by petroleum hydrocarbons is common in anthropogenically impacted coastal waterways but the effects of petroleum hydrocarbons on water column oxygen are difficult to predict because the hydrocarbons can be used as a carbon source by heterotrophic bacteria, but also may cause toxicity. Oil concentration and temperature are also likely to influence the outcome. In many aquatic environments, autotrophy and heterotrophic decomposition of oil are both nitrogen limited. However, N-limitation of either process is unlikely in the Hudson, given extremely high anthropogenic N-loading. To examine the effects of crude oil on the balance of autotrophy and heterotrophy in a nutrient-rich environment, experiments were conducted using water collected from the Hudson River Estuary from winter to summer. An emulsion of light sweet crude oil was added to oxygen bottles at a range of concentrations (0-250 ppm), that were incubated at ambient temperatures for ~2 d. The change in oxygen levels in light and dark bottles during incubation was used to quantify the impacts of the oil additions on heterotrophy and autotrophy. The fresh crude oil emulsion was toxic to autotrophy at much lower concentrations than heterotrophy. However, the heterotrophic response may have been more sensitive to temperature. These results will help predict how contamination by petroleum hydrocarbons will impact estuarine oxygen dynamics.

P2-176 YOUNG, CM*; MORAN, CJ; GERRY, SP; Fairfield University; *caroline.young1@student.fairfield.edu*

Effects of temperature on the escape response of cunner

Cunner (*Tautogolabrus adspersus*) are a temperate species from the family Labridae that inhabit the Western Atlantic. Therefore, this species experiences temperatures ranging from 0 °C to 25 °C. Once temperatures drop below 10 °C in Long Island Sound, cunner find shelter to enter into extended torpor. It is not known how temperature might impact the escape response of cunner and thus influence hibernation. Previous studies have shown that acclimation to low temperatures inhibits locomotor muscle, which significantly lowers steady swimming performance. We examined the impact of temperature on the fast-start escape response of cunner. We hypothesized that cunner will exhibit a faster escape response at higher temperatures. Four predator escape responses were recorded at 250 frames s^{-1} for six cunner at each temperature (20 °C, 15 °C, 10 °C, and 5 °C). We compared peak, minimum, and average center of mass (COM) velocities and accelerations among temperatures. Average COM velocity was faster at 20 °C than 10 °C or 15 °C. Similarly, peak COM velocity and acceleration were faster at 20 °C than at 10 °C. These findings further support our observations that swimming performance is inhibited at lowered temperatures. We expect that rising ocean temperatures will shift the range of this species and impact swimming and torpor behaviors.

P2-177 YOUNG, VKH*; BAEZA, JA; BLOB, RW; Saint Mary's College, Clemson University; *vyoung@saintmarys.edu*

Limb Bone Scaling of Functionally Divergent Turtle Clades

Transitions from terrestrial to aquatic habitats by vertebrates are often accompanied by the evolution of flattened limbs for swimming via dorsoventral flapping. Changes in bone loading during limb use in swimming might facilitate such changes in shape. Studies of turtles found that torsion is high relative to bending on land, but low compared to bending during aquatic rowing. Release from torsion could have facilitated the evolution of flattened limbs that later evolved in flapping aquatic species. Rowing has been regarded as an intermediate behavior between walking and flapping; thus, rowing species might show limb bone flattening intermediate between the tubular bones of terrestrial walkers and the flat bones of marine flappers. We measured the humerus and femur of museum specimens from four functionally divergent turtle clades: sea turtles (flappers), softshells (specialized rowers), emydids (generalist rowers), and tortoises (terrestrial). We compared patterns of limb bone scaling with body mass across lineages using phylogenetic comparative methods. Rowing taxa did not show intermediate scaling patterns between tortoises and sea turtles, but our data provide other functional insights. For example, flattening of sea turtle limb bones relates to positive allometry in the limb bone diameter perpendicular to flexion-extension, rather than negative allometry of the flexion-extension diameter. Moreover, softshells show positive allometry of femoral diameters that may provide additional weight to compensate for a reduced shell, helping to maintain a benthic position. Tortoise limb bones showed positive allometry in diameter, as well as relatively long humeri, potentially helping to resist high strains associated with digging. Thus, scaling patterns of some turtle lineages may correlate to their distinctive locomotor habits.

P1-123 YOUNG, EB*; KANE, EA; Georgia Southern University; *ey00364@georgiasouthern.edu*

Heritability of morphological traits across divergent environments in guppies

In an ever-changing environment, it is vital for beneficial traits to be passed on to each generation to ensure survival of the species. But how well these traits can be passed from parents to offspring depends on their heritability. Trinidadian guppies (Poecilia reticulata) have repeatedly adapted to changes in predation regime and resource availability such that changes in body shape are advantageous in the respective habitat. Therefore, these traits should be heritable across generations and differences in heritability of these traits may provide an adaptive advantage. However, heritability may be governed more at the species rather than population level, resulting in little difference in heritability across populations. But whether certain traits are more heritable than others, and how this may differ between populations, is poorly understood. We will test whether, in high predation environments where an escape response is important for survival, tail and peduncle size may be more heritable compared to low predation environments where feeding and other behaviors necessitate maneuverability, shape of the pectoral and other fins may be more heritable. To test this hypothesis we will photograph wild-caught females and their first-generation lab-reared daughters using a custom v-shaped acrylic tank that allows live, alert fish to maintain a natural fin and body posture. Morphological characters, such as standard length, caudal peduncle length and height, tail area, dorsal and pectoral fin length will be quantified from these photographs using Image J and compared between generations and populations. Strong similarity between generations, but differences across populations will suggest that traits are heritable but that this heritability changes across populations.

P1-221 YOUNG, KG*; VANDERBOOR, CM; REGNAULT, TRH; GUGLIELMO, CG; Western University; *kyoun24@uwo.ca*

Method for the Isolation and Growth of Skeletal Muscle Progenitor Cells of Yellow-rumped Warblers (Setophaga coronata)

Skeletal muscle is a highly active tissue that facilitates locomotion, thermoregulation and is a main driver of overall daily metabolic rate in vertebrates. Migratory birds are of particular interest for studying exercise performance and muscle physiology because of their ability to undergo extreme endurance flights and their high rates of fat metabolism. Mechanistic cell culture experiments provide access to specific isolated aspects of muscle biochemistry and physiology that are inaccessible in live animals. However, previous methods to isolate skeletal muscle cell progenitors for cell culture from birds are limited in scope to agriculturally important animals, most frequently at the embryonic or fetal stage of development. We present an adapted method for isolating primary skeletal muscle satellite cells for cell culture experiments from adult Yellow-rumped Warblers (*Setophaga coronata*) and characterize their phenotype and growth *in vitro*. While methods for isolating skeletal muscle satellite cells from adult human, rodents and embryonic birds in studies of muscle related pathologies are well established, this is the first reported isolation and growth of muscle progenitors from adult birds in culture. These methods allow for experimental manipulations inaccessible to whole animal studies and in a species that cannot be bred in captivity.

94-5 YOUNG, RC*; KITAYSKY, AS; DRUMMOND, HM; Universidad Nacional Autónoma de México, México City, University of Alaska Fairbanks, USA;
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Intergenerational telomere dynamics in the blue-footed booby (Sula nebouxii)

Telomere dynamics are increasingly used as an indicator of individual quality in ecological systems. We explored telomere dynamics in a long-lived tropical seabird, the blue-footed booby (*Sula nebouxii*). We predicted a slow telomere loss rate, to support a long lifespan, and a positive relationship between telomere length and fitness prospects, if telomeres are indicating individual quality. There was a cross-sectional negative relationship with chronological age (adults aged 2-22), and females lost telomere length more rapidly than males, which has been demonstrated in other bird species. Individual telomere length did not predict the survival of adults or chicks over six years, but parental telomere lengths interacted to predict chick recruitment. Unusually, boobies do not mate assortatively by chronological age, but there was strong assortative mating by telomere length, raising questions about the function and mechanism of this assortment, and its relation to the effect on chick recruitment. Previously assortative mating by telomere length has only been seen in tree swallows. Lastly, as a DNA-based character affecting fitness, telomere length is likely heritable. Using our unique dataset, we addressed heritability by comparing parental telomere lengths to offspring telomere lengths. Heritability was strongest through the mother, although correlations showed strong heritability between siblings and from mean parental telomere length as well. Thus, telomere length is a heritable trait in boobies, predicts with fitness outcomes, and either directly or indirectly indicates mate choices.

S7-5 YU, K*; ARMENDARIZ, A; MA, J; KING, D; Exploratorium;
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"I have a GREAT idea for an exhibit!" - Adapting scientific research for museums

Collaborating with scientific researchers is an essential practice for museum educators. However, adapting scientific findings and practices into compelling learning experiences for museum visitors is a challenging and nuanced undertaking, particularly in the life sciences. In this session, former research scientists turned museum professionals will discuss how findings, methods, and technologies from current biological research have been incorporated into exhibits, demonstrations, and other museum programming. Through a set of case studies from the Exploratorium, a museum of science, art and human perception in San Francisco, we illustrate the promises and pitfalls of this process to support learning in museums.

98-6 YUAN, ML*; WAKE, MH; WANG, IJ; University of California, Berkeley; *michael.yuan@berkeley.edu*

Phenotypic Integration and Convergence of Claw Morphology in Caribbean Anolis Lizards

The adaptive radiation of Greater Antillean anoles is characterized by a suite of phenotypes associated with partitioning of vertical habitat. Yet, studies have largely overlooked the role of claw morphology in habitat specialization across the anole radiation. Claws can play an important role in clinging ability, with thicker and more curved claws broadly associated with greater clinging performance in squamates. Using museum collections, we tested if claw shape corresponds with ecomorph classification in Greater Antillean anoles and if character displacement in claw shape is observed on two species islands relative to single species islands in Lesser Antillean anoles. Additionally, we compared patterns of phenotypic integration for toepads and claws across three radiations of anoles: the Greater Antilles, the Northern Lesser Antilles, and the Southern Lesser Antilles. Unlike mainland anoles, arboreality did not predict claw morphology in Greater Antillean species. Rather, we found that claw morphology is associated with perch diameter in Greater Antillean anoles with grass-bush and twig anoles having shorter, thinner, and flatter claws than other ecomorphs. Additionally, we found no evidence for habitat association or character displacement of claws in Lesser Antillean anoles. Taken together our results are consistent with the convergent evolution of claw morphology in response to habitat partitioning in Greater Antillean anoles. However, different evolutionary dynamics appear to be influencing claw evolution in the Greater Antillean radiation compared to the Lesser Antillean and mainland radiations.

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Regional Scale Connectivity Among Barnacle Populations in the Gulf of Maine Inferred from the Phenology of Larval Release and Settlement

Demographic population connectivity can be assessed via a variety of methods, but all of the standard approaches require significant effort and funding to implement. In systems that are characterized by strong latitudinal gradients in spawning time (or larval release) and settlement, regional scale connectivity can also be estimated by spatial variation in the correlations among these events. I monitored the timing of larval release in 9 widely separated barnacle (*Semibalanus balanoides*) populations in the Gulf of Maine and the temporal patterns of settlement in a subset of 7 of these populations during the spring and summer of 2017. Populations were distributed inshore of two different oceanographic regimes; the Eastern and Western Maine coastal current systems (EMCC vs. WMCC). Laboratory estimates of pelagic larval duration were combined with cross-correlation analyses to infer connectivity from timing data. Larval release data indicated the existence of two gradients in spawning time that ran in opposite directions along the coast. Settlement was bimodally distributed in the south, grading into a unimodal distribution further north. Cross-correlation results suggest that early season settlement in populations inshore of the WMCC was driven by larval supply from populations in that same region, but late season settlement was derived from natal population associated with the EMCC, while settlement inshore of the EMCC was entirely derived from natal populations within that same region. Although this approach does not fully resolve population-level connectivity patterns, it is relatively inexpensive and easy to implement and regional scale patterns are often adequate for many management purposes.

71-4 ZAJIC, DE*; PODRABSKY, JE; Portland State University; *zajic@pdx.edu*
The role of γ-aminobutyric acid metabolism in survival of anoxic and desiccated annual killifish embryos
In most organisms, even brief episodes of low oxygen supply can cause irreparable damages to vital organs, such as the brain and heart. The annual killifish (*Austrofundulus limnaeus*) survives in ephemeral ponds and their embryos have the remarkable ability to tolerate anoxia for months. In addition, *A. limnaeus* must also contend with the seasonal dehydration of their ponds, which they survive through mechanisms that likely highly limit gas exchange. We propose that anoxia tolerance is a pre-adaptation that allowed the evolution of dehydration tolerance. Thus, we predict that *A. limnaeus* embryos exposed to dehydrating conditions will show similar responses at the molecular level to embryos exposed to anoxia. When exposed to anoxia, embryos of *A. limnaeus* respond by producing significant amounts of γ-aminobutyric acid (GABA) and lactate. When exposed to desiccation, embryos of *A. limnaeus* also respond by producing significant amounts of GABA, though at a slower rate than when exposed to anoxia. This study aims to understand the role of GABA and lactate in supporting the metabolic response to anoxia and desiccation across development. In addition, this study explores the roles of glutamate decarboxylase (GAD) activity and metabolic rate in determining the rate of GABA and lactate accumulation in response to anoxia and desiccation. GABA has been found to provide excitatory actions in the developing vertebrate nervous system, but conversely, typically functions as an inhibitory neurotransmitter in adults. The high levels of GABA accumulated during anoxia and desiccation in *A. limnaeus* embryos suggests GABA may serve a purpose other than as a neurotransmitter when embryos are under stress.

133-4 ZAKROFF, CJ*; MOONEY, TA; Woods Hole Oceanographic Institution; *czakroff@whoi.edu*
Impacts, Variability, and Resiliency in Hatchling Squid, Doryteuthis pealeii, Paralarvae after Chronic Embryonic Exposure to Acidification and Warming
Ocean acidification (OA) and warming due to increased anthropogenic CO2 is a significant concern for coastal systems and species. The Atlantic longfin squid, *Doryteuthis pealeii*, a keystone of the Northwest Atlantic trophic web, has demonstrated impacts (decreased mantle length, delayed hatching, and degraded statoliths) under high chronic exposure to acidification (2200 ppm), but the combined effects of OA and warming have not been explored. In this study, *D. pealeii* egg capsules were reared under a combination of acidification levels (400, 2200, & 3500 ppm) and temperatures (20 & 27 ºC). Hatchlings were measured for a range of morphological and physiological metrics in three trials over the 2016 breeding season (May - Oct). While some trials mirrored previous results of OA impacts, others showed greater resilience, demonstrating notable clutch variability in this organism's stress response. Surprisingly, increased temperatures did not appear to exacerbate OA impacts, although responses were variable. Rather, high OA-exposed hatchlings from the warmer conditions often showed reduced impacts compared to those reared in ambient temperatures. This may be due to the increased developmental rate and subsequently reduced OA exposure time of embryos in the higher temperature treatment. The viability and survivability of these high OA, high temperature hatchlings could not be observed, however. Therefore, these results indicate a substantive potential plasticity to multiple stressors in the early life stages of this species of squid, but do not determine how this species would fare in the future ocean.

40-3 ZAMORANO, L.S.*; KAVANAUGH, D.H.; ERWIN, T.L.; California Academy of Science, Smithsonian Institution, National Museum of Natural History; *lzamorano@calacademy.org*
Drivers of diversification in a continental radiation of ground beetles (Coleoptera: Carabidae: Lachnophorini)
Understanding the factors responsible for heterogeneity in species diversity among different habitats is major challenge in evolutionary biology. The Amazon Basin harbors the highest species richness for a variety of groups, yet whether the Amazon is a cradle or museum of diversity continuous to be an open debate. In this study, we evaluate the phylogenetic relationships of an assemblage of beetles found in seven different habitats within a lowland tropical rainforest in the Ecuadorian Amazon. A set of 2 nuclear and 2 mitochondrial genes were used to infer a time-calibrated phylogeny of 31 species of Lachnophorini beetles (Carabidae: Coleoptera) from the western Amazon Basin. We determined the patterns of diversification using a lineage through time (LTT) plot to determine whether these beetles represent an adaptive or evolutionary radiation. The LTT analysis suggested a late-burst pattern of diversification. We complemented the phylogenetic relationships with a comprehensive dataset on the habitat occupancy of the species compiled during 4 years of fieldwork and 2-D geometric morphometric data. We used these datasets to ascertain whether the diversification pattern of the beetle species was associated with variation in habitat use and morphological differentiation. We found that Lachnophorini beetles late burst diversification was linked with significant disparity in morphological shape among the species assemblage. In addition, most of the morphological variation was structured according to microhabitat use. Together, the results obtained enables making inferences about the evolutionary mechanism that generated the large diversity of these beetles in the Amazon Basin.

72-1 ZAMORE, S*; SOCHA, JJ; Virginia Tech; *jjsocha@vt.edu*
Head wagging and visual acuity in flying snakes (Chrysopelea)
The arboreal flying snake is an adept glider with keen vision, but little is known about the role of their visual system in glides and other behaviors. These animals are well-camouflaged and elusive, making their ecology difficult to study. However, the ecological role of the visual system can be gleaned from their behavioral responses. For example, flying snakes are known to track planes and birds overhead, suggesting they may be predated upon by birds. These qualitative observations can also help illustrate visual functions driving some behaviors.

Recently, we have conducted optomotor experiments to measure visual acuity in flying snakes. These experiments involved lateral, visual field rotation for 1-4 minutes in a constant direction. During these experiments, we observed a novel behavior: a lateral, oscillatory translation of the head that occurs with a frequency of about 2 Hz. In the context of this experiment, this behavior does not appear to be used for motion parallax because it occurs in response to whole-field visual motion, not a small-field target, as seen in other animals. This behavior is similar to a recently-described oscillatory head motion in garter snakes that was characterized as a type of behavioral camouflage. We hypothesize that this novel flying snake behavior, head wagging, is another example of such behavioral camouflage.

In this talk, we present evidence of head wagging in two species of flying snake (*Chrysopelea paradisi*, *Chrysopelea ornata*) in response to whole-field visual motion, and describe the triggering stimuli. This characterization provides useful insight into the behavioral roles of vision in locomotor behaviors, including non-gliding behaviors. Supported by NSF 1402558 and 1351322.

82-3 ZANI, PA*; NELSON, BA; LUO, CH; Univ. Wisconsin-Stevens Point; *pzani@uwsp.edu*

Life-History Shift in Storage across Latitudes in Side-Blotched Lizards Suggests Climate Is Not Limiting at Higher Latitudes

Many ecological studies support the idea that the importance of biotic limits (e.g., predation) decreases with increasing latitude, just as the importance of abiotic limits (e.g., climate) increases with latitude. Thus, as latitude increases, the life-history strategy of species should shift from being limited by biotic to abiotic factors. We tested for shifts in life-history strategy across a latitudinal gradient in a widespread lizard, common side-blotched lizards. We hypothesized that growth rate and energy storage will increase with latitude due to shorter growing seasons and to withstand longer, harsher winters, respectively. We reared side-blotched lizards from 12 populations from Nevada (mid-) and Oregon (high-latitude) under common lab conditions to measure their growth rates and quantify their energy storage prior to winter. Contrary to our expectations, lizards from low latitudes had higher growth rates and greater energy storage than those from higher latitudes suggesting that high-latitude populations are not limited by either the local predation environment or winter harshness. However, results suggest that populations from mid latitudes (i.e. central Nevada) are limited by both predation and winter mildness requiring both rapid growth and high energy storage.

P1-120 ZARANSKY, S*; GIBILISCO, M; WATANABE, A; HOFFMANN, S; NYIT College of Osteopathic Medicine, Old Westbury, University College London, UK; *szaransk@nyit.edu*

Postnatal Ontogeny of Inner Ear Morphology in Chicken and Alligator

Due to its critical role in sensing motion, the vestibular system of the vertebrate inner ear is expected to undergo evolutionary changes concomitant with major shifts in locomotor mode. While previous comparative studies have examined the relationship between inner ear morphology and locomotor performance across taxa, the potential link through ontogeny, such as the onset of flight, has been seldom addressed. To examine ontogenetic changes in inner ear anatomy, we used high-resolution computed tomography (CT) imaging on postnatal developmental series of alligators and chickens, two model archosaurs with disparate locomotor mode. We employed a high-dimensional 3-D geometric morphometric (GM) approach to (1) test the difference in ontogenetic trajectories of semicircular canal (SCC) shape, and (2) compare the disparity between taxa and individual SCCs. The results indicate that alligators and chickens exhibit distinct ontogenetic modes for SCCs and display contrasting pattern of ontogenetic disparity across SCCs. Semicircular canals show greater overall disparity in chickens than in alligator. Chickens exhibit similarly high disparity in both the anterior and lateral SCCs whereas alligators exhibit the greatest disparity in the posterior SCC. Notably, chickens show a different ontogenetic trajectory 1-2 weeks after hatching, which may correspond to the onset of limited flying capability. Through synthesis of micro-CT imaging and GM methods, this study provides important insight into the potential link between ontogenetic changes in locomotor mode and inner ear anatomy.

P2-42 ZAVALETA, J/A*; ROSERO, M; FUSE, M; San Francisco State University; *jhony.zavaleta@gmail.com*

Regulation of allometric growth after imaginal disc damage in the tobacco hornworm, Manduca sexta

Experiments in *Manduca sexta* and other holometabolous insects have shown that damage to imaginal tissues at early larval stages delays the onset of metamorphosis. These delays in development are assumed to be the result of a mechanism to allow for regeneration of the damaged tissues and regulation of growth of undamaged ones. Putatively, this regulation of growth, known as body allometry, ensures that the recovered animals develop into adults with properly scaled bodies. It is not known, however, if these assumptions are true that developmental delays allow organisms to conserve their body allometry. Therefore, we have hypothesized that the observed delays in development are the result of a mechanism designed to conserved the body allometry of an organism despite damage to progenitor tissues. In this particular study we assessed changes in the body allometry of *M. sexta* after varying levels of damage to its imaginal discs via different doses of X-ray radiation to selectively damage imaginal discs. We then tracked recovering animals until adulthood, at which point we measured the growth rate of various appendages in comparison to the body and used these measurements to determine the scaling factor and allometric coefficient by means of a standard major axis (SMA) linear regression. Preliminary data suggests little to no variation in the scaling factor or allometric coefficient at low doses. We will then discuss in detail the extent at which body allometry was conserved with respect to the adult's appendages and what this could imply toward the regulation of the developmental checkpoints in the animal.

P2-267 ZEB, AJ*; PAYNE, AA; JOHNSON, MA; Trinity University; *azeb@trinity.edu*

Evolution of neuromuscular junction size and muscle use in Anolis lizards

Neuromuscular junctions (NMJ) connect an animal's nervous system to its muscular system, and are a critical component in the behaviors that result from muscle contractions. Yet, little is known about how the size of NMJs (which determines the extent of the motoneuron's connection to a muscle fiber) varies in association with behavioral use of a muscle. In this study, we examine whether variation in the use of a muscle is positively correlated with variation in NMJ size. We studied 27 *Anolis* lizard species from the Dominican Republic, Puerto Rico, the Bahamas, and the southeastern USA. First, we observed their use of two muscles: the ceratohyoid (CH), which controls the movement of the dewlap, a throat fan used in courtship and aggressive displays; and the retractor penis magnus (RPM), the muscle that controls movement of the hemipenes during copulation. Then, we dissected the CH and RPM from adult males of each species, and then stained the muscles for acetylcholinesterase, an enzyme that is concentrated in the NMJ. We then measured the cross-sectional area of the NMJs in each muscle. Results show that NMJs in the CH (a muscle used multiple times per min) are much larger than NMJs in the RPM (a muscle used, at most, several times per day). Our preliminary analyses of a subset of 15 species suggest that the size of NMJs in the CH is associated with CH fiber size, but not dewlap display behavior, and that the size of NMJs in the RPM is not associated with RPM fiber size or copulation rate. This comparative study of NMJ size, which varies widely among species and even among muscles within an individual, contributes to our understanding of the evolution of muscle physiology and behavior.

P2-240 ZERULLA, TC*; STODDARD, PK; Florida International University; *tzeru001@fiu.edu*

Social Behavior Differences Between Males Exhibiting a Color Polymorphism in the Eastern Mosquitofish (Gambusia holbrooki)

Polymorphisms contribute to adaptive plasticity because individuals with different phenotypes can respond differently to environmental variation. These phenotypes are often a suite of correlated traits spanning physiology, morphology and behavior. Eastern Mosquitofish (*Gambusia holbrooki*) males are either a common silver or rare melanistic (white with black blotches) phenotype, but no detailed analysis of their behaviors across social settings exists. We investigated the behavior of melanistic and silver males alone as well as interacting with another male, with a group of females, and with both another male and a group of females. Based on previous studies, we hypothesized that melanistic and silver males will differ in social behavior. Specifically, we predicted that melanistic males will exhibit higher levels of aggression and more mating attempts than silver males. Fish were placed in a five-gallon aquarium and each scenario was video recorded for one hour. First, we described all the focal males' behavioral acts and compiled them into an ethogram. Behaviors were then scored continuously in JWatcher. Time analyses of behavior were used to determine if the frequency of aggression and mating behavior changes over time. We also applied a Markov chain analysis to compare sequences and transition probabilities of aggression and mating for both phenotypes. Melanistic males are hypothesized to exhibit a different sequence of behavioral acts during aggression and mating. We present a standardized description of Eastern Mosquitofish social behavior for color polymorphic males. These results form a strong foundation for future studies investigating the genetic and environmental mechanisms underlying phenotypic covariation in this and similar species.

128-6 ZHANG, Y*; TAYLOR, H; KASH, M; KAVAZIS, AN; ROBERTS, MD; HOOD, WR; Auburn Univ.; *yzz0095@auburn.edu*

Induced ROS exposure improves mitochondrial performance in hepatocytes

Reactive oxygen species (ROS) can induce oxidative stress, but ROS also serve as signaling molecules that can lead to improve cellular performance. In a prior study, we characterized the temporal response to induced ROS production via X-irradiation in mice. Our results show that liver mitochondrial damage increased 24 h post exposure, but the liver displayed improved markers of mitochondrial function 10 days after X-irradiation. This adaptive response is referred to as mitohormesis. To identify the mechanisms associated with this effect, we asked if AML12 (mouse) hepatocytes displayed a response to radiation that was similar to our previous study. We evaluated temporal changes in the cells following 25 cGy of X-irradiation by measuring mitochondrial function and ROS emission 1, 24, 48, and 72 h after X-irradiation. Complex I and II substrate driven mitochondrial respiration was higher than controls at 72 h after irradiation, whereas complex IV substrate respiration decreased at 1 hour after irradiation but increased to control levels 48 h post-irradiation. ROS emission levels increased 1 h after irradiation, but returned to control levels at the 48 h post-irradiation time point. These data show that mild exposure of ROS benefits mitochondrial respiratory performance. Moreover, this study also provides a framework for future studies investigating the mitohormetic response.

32-5 ZHANG, VY*; WILLIAMS, CT; PALME, R; BUCK, CL; Northern Arizona Univ., Univ. of Veterinary Medicine, Vienna; *vyz3@nau.edu*

Relationships Between Cortisol and Activity Patterns in Free-living Arctic Ground Squirrels

Little is known of the relationship between glucocorticoids and specific behavioral outcomes in free-living mammals. In this study, we used collars affixed with accelerometers and light loggers to measure the above-ground overall dynamic body acceleration (ODBA), an index of activity-specific energy expenditure, across the active season on free-living artic ground squirrels (*Urocitellus parryii*). In addition, we measured fecal cortisol metabolites (FCM) to non-invasively assess adrenocortical activity of squirrels across their active season. Female FCM concentrations were highest during the mid-lactation interval and lowest during post lactation, while male FCM did not vary across the active season. Overall, males had higher baseline FCM levels than females across the year (male LS-mean = 6.2, SE = 0.10; female LS-mean=5.7, SE=0.08). Levels of above-ground activity were consistent with expectations of reproductive demand; activity levels of males were higher than females during the mating period and lower than in females during the mid-lactation period. Cold and wet weather, which is known to adversely affect conditions of thermal exchange, increased FCM and decreased above ground activity levels in both sexes. The effect of weather on FCM concentrations was greatest in the early season, possibly due to reduced forage availability associated with early springtime in the Arctic. Lastly, our results suggest that a negative relationship between FCM concentrations and intensity of above-ground activity exists for female but not male, arctic ground squirrels. Collectively, this study furthers our understanding of how reproductive state and environmental conditions may interact to affect behavioral patterns and adrenocortical activity in free-living mammals.

P2-237 ZHANG, D; GABALDON, J; ROCHO-LEVINE, J; VAN DER HOOP, J; MOORE, M; SHORTER, KA*; SHORTER, KENNET; University of Michigan, Dolphin Quest Oahu, Arhus University, Woods Hole Oceanographic Institution; *kshorter@umich.edu*

Putting on the brakes: the effect of drag loading on the maneuverability of bottlenose dolphins

Marine mammals hunt highly maneuverable prey and must make complex movements during foraging events. Maneuverability is in turn dependent on stability of the fluid around the animal and is related to morphological structure. While maneuverability is essential, it is challenging to quantify through direct observation in the marine environment. Animal locomotion tends to be estimated from a combination of GPS, inertial measurement unit (IMU), and pressure data collected from bio-logging tags. However, assumptions about animal speed between sparse GPS updates can misrepresent the actual dynamics of the animal. Furthermore, it is difficult to assess estimated track quality in the wild, because animal observations that are independent of tag data are difficult to obtain. Our work addresses this through development of an optimized localization technique and dynamics analysis methods that combine measured animal dynamics from bio-logging tags with position and speed estimates derived from overhead video data in a controlled experimental environment. We utilize these tools to investigate how a perturbation to the stability of the fluid around the body, created by drag loading, affects the swimming biomechanics and maneuverability of bottlenose dolphins (Tursiops truncatus) during a controlled swimming task. To create drag, neutrally-buoyant modules with known hydrodynamic properties were attached to either side of the tag. Four animals were trained to perform the experiment, and our results capture significant changes during both straight-line swimming and cornering behavior with the added drag loading.

4-7 ZHANG, B*; ROBERTS, KT; DAHLHOFF, EP; WHEAT, CW; WEISSELBERG, S; RANK, NE; Sonoma State University, UC Berkeley , Santa Clara University , Stockholm University; *zhangbo@sonoma.edu*

The Power Within: Relationship Between Endosymbiotic Bacteria and the Stress Response in a Montane Leaf Beetle

Insects serve as hosts to diverse microbial endosymbionts. Recent studies suggest that microbial endosymbionts may affect performance characters that reflect the ability of insects to respond to environmental stress. Insects living in montane habitats face many environmental stressors, including temperature, precipitation, and low oxygen. We examined the problem of how microbial endosymbionts affect performance in Sierra Nevada (California) populations of the leaf beetle *Chrysomela aeneicollis*, in which prior studies show evidence of local adaptation to temperature. Metagenomics analysis using Metaphlan2 of populations from three drainages distributed along a latitudinal thermal gradient revealed that 90% of sequences were similar to known species of *Wolbachia*. Analysis of 90 beetles collected in the central drainage, Bishop Creek, revealed that all were infected by two species of *Wolbachia*: one belonging to the WolA lineage, the other WolB. We used quant-PCR to assess the relationship between abundance of each *Wolbachia* strain in adult beetles exposed to either sub-lethal cold or control conditions in the laboratory; cold treatment corresponded to conditions beetles experience in nature. Running speed after stress exposure was significantly slower after exposure to cold for all beetles. We are currently studying the relationship between different concentrations of *Wolbachia* A and B strains in these experimental beetles, and how this affects running speed after cold exposure. Our findings will reveal whether this endosymbiont alters physiological responses to thermal stress in a native insect that has been documented to be under temperature selection.

P2-230 ZHAO, D*; SACHDEVA, V; REVZEN, S; University of Michigan, Ann Arbor; *shrevzen@umich.edu*

Modeling Multilegged Locomotion: the Friction Dominated Limit

Most legged locomotion occurs while animals are contacting the ground with multiple legs at a time, posing difficulties for modeling due to uncertainty about inter-leg force distribution and foot slipping outcomes. Just as the motion of small swimmers is friction dominated at low Reynolds numbers, the ratio of inertial to friction forces may make small legged animals friction dominated as well. If this were the case, a simplified "connection" model taking egocentric leg motions as inputs may be able to reproduce foot slippage and body center of mass motions. We present such a model, and its validation using data from running *Blaberus discoidalis* cockroaches. Such simplified models may help explain how multilegged animals control and plan their motions, and shed light on interactions between morphology and locomotor performance.

106-3 ZHAO, M*; SALTZMAN, W; Univ. of California, Riverside; *mzhao002@ucr.edu*

Being A Single Mother California Mouse

Being a mother is energetically costly for mammals and is associated with pronounced changes in mothers' physiology, morphology and behavior. In ~5% of mammals, fathers assist their mates with rearing offspring and can enhance pup survival and development. Although these beneficial consequences of paternal care can be mediated by direct effects on offspring, they might also be mediated indirectly, through beneficial effects on mothers. We tested the hypothesis that fathers in biparental species reduce the burden of parental care in their mates, and therefore that females rearing offspring with and without assistance from their mates will show differences in physiology, morphology and behavior, as well as in survival and development of pups. Using the monogamous, biparental California mouse (*Peromyscus californicus*), we compared measures relevant to metabolism and emotionality among mothers rearing pups with and without their mates, as well as nonbreeding females. We also monitored development of pups. Half of the animals in each reproductive group were housed under standard laboratory conditions and the other half in cages requiring them to climb wire mesh towers (~8 cm in diameter and ~50 cm in height) to obtain food and water. Preliminary data indicated that single mothers approached a novel object more quickly ($P = 0.024$) and performed more sniffing and touching of the novel object ($P = 0.014$), compared to both paired mothers and nonbreeding females. Both single and paired mothers had higher liver mass than nonbreeding females ($P = 0.021$). Neither reproductive nor housing condition significantly affected litter size, pups' body mass or age of eye opening. Ongoing analyses are expected to reveal additional effects of mate absence on mothers' physiological, morphological, and behavioral responses to motherhood. Supported by NSF IOS 1256572

132-3 ZHEXIN, X; DOMEL, A; WENGUANG, S; KNUBBEN, E; WEAVER, J; BERTOLDI, K; WEN, L*; Beihang University, Harvard University, Festo Corporate Bionic Department; *liwen@buaa.edu.cn*

A Bio-inspired Soft Robotic Gripper Inspired by the Cephalopod Tentacles

The tentacles of the cephalopods (such as octopus) are usually cone-shaped and highly variable in the taper angle across species. For example, the octopus variabilis has long and slender tentacles, while the octopus ovulum possess short and brawny tentacles. Inspired by this unique morphological feature, we designed and fabricated a pneumatically actuated, cone-shaped soft robotic tentacle, thereby adding to the conventional soft robots designs whose transverse section usually maintain constant across the height. A series of cone-shaped tentacles were fabricated with a uniform height of 200 mm, but with different taper angles. Combining the parametric modeling, which allows for investigations of tentacle kinematics in a systematic manner, and the experiments of the soft robotic prototypes, we examined the effect of the taper angle on the performance of the tentacle (i.e., the bending angle, the curvature, and the force exterted by the robot) across a range of pneumatic pressures (0-300kPa). The bending kinematics show that the tentacle with a small taper angle resulted in a spiral shape with a bending curvature that are significantly greater than the tentacle with a large taper angle. In contrast, the force outputs of tentacles showed opposite responses concerning the taper angle. We further speculate that there is a performance trade-off between bending capacity and force output in regards to the taper of the tentacle. Furthermore, we implemented a prototype "OctopusGripper" with rows of flexible suction cups assembled on the soft tentacle. With the aid of the suction cups empowered by vacuum, the tentacle can wrap around and grip a variety of objects with different sizes and shapes (https://www.youtube.com/watch?v=ZPUvA98uSj8).

132-6 ZHU, R*; ZHONG, Q; QUINN, DB; ZHU, J; BART-SMITH, H; Univ. of Virginia; *rz6eg@virginia.edu*

Effects of Tail Planform Shape on Stability and Propulsive Performance of Bio-Inspired Swimming

Trailing edge sweep angle is found to affect the stability, thrust, and efficiency of a rigid panel with a bio-inspired planform. Each panel has a square shaped peduncle, a leading edge with fixed sweep angle (45°), and a trailing edge with sweep angles that range from 60° (concave) to 120° (convex). The panels are suspended in a water tunnel and actuated with sinusoidal pitching motions that span the optimal Strouhal number range (0.2-0.4). For each motion, we measure the self-propelling speed, then explore swimming stability by freeing the panel to move in both the streamwise and lateral directions. Stability and propulsive performance are quantified via a force sensor and paired with PIV (Particle Image Velocimetry) data to study the wake topology behind the panel.

24-8 ZHUANG, MV*; RUSSELL, AP; HIGHAM, TE; Univ. of California, Riverside, Univ. of Calgary; *mzhua001@ucr.edu*

The Evolution of Digit Morphology in Relation to the Acquisition of the Adhesive System

The evolution of novel traits is often associated with large-scale morphological changes that are reflected both externally and internally. For vertebrates, many novel traits associated with feet have emerged, and these are often related to locomotion. This is especially true for morphological changes accompanying the gecko adhesive system. Digit morphology and the arrangement of the adhesive apparatus around the foot can dictate the orientations at which a gecko can adhere. Previous research described changes in the digit morphology among gekkotans and observed trends towards symmetry within the foot that appeared to precede the evolution of the gecko adhesive system. Using a phylogenetic comparative framework, we reanalyzed the data from this study and applied geometric morphometric analysis to additional data obtained from X-Ray scans in order to examine patterns of morphological evolution in association with the gain and loss of adhesive capabilities, as well as transitions in habitat. Our sample includes at least five origins of the adhesive system, as well as several cases of secondary loss or reduction. Our results confirm that pad-bearing lineages tend to have shorter digits and larger inter-digital angles than padless lineages, and this suggests repeated shifts to a similar pad-bearing morphology. Changes in the shape of the foot in association with the adhesive system also suggest changes to proximal elements of the foot, including the bones comprising the ankle joint. These evolutionary patterns of morphological change demonstrate the hierarchal nature of the gecko adhesive system and foot morphology. Supported by NSF IOS 1147043.

P1-69 ZIADI, P*; ANDERSON, R; Florida Atlantic University; *mziadi@fau.edu*

Testing song type matching hypotheses in the Bachman's sparrow (Peucea aestivalis)

One hypothesis for the function of vocal repertoires in songbirds is that singing multiple song types facilitates song type matching. Song type matching occurs when a male replies to the song of another male by singing the same song type. Song type matching has been hypothesized to have a number of social functions and was recently shown to be a reliable early threat signal in the song sparrow. To date, the majority of studies on song matching have focused on species with small to moderately sized repertoires (< 15 song types). Bachman's sparrow repertoires range from 35-45 song types, and our field observations suggest that neighboring males perform song type matching during countersinging interactions. We tested the hypothesis that song type matching is an aggressive signal in Bachman's sparrows through simulated territorial intrusions using a replica of a male Bachman's sparrow coupled with playback of self-song types, ensuring the possibility of a full match. Subjects were played 9 of their own song types, each repeated 3 times. Each subject received two treatments: 1) songs were presented in random order (e.g, CEADB), and 2) songs were presented in the sequence in which the bird sang them during an undisturbed singing bout (ABCDE). During playbacks we took behavioral measures of aggressiveness and recorded all song responses. Subjects did not perform type-matches at above chance levels during either treatment, and we found no difference in aggressive response to the two treatments. Chance matching probabilities are low in a species with large repertoires, yet we commonly observe neighboring males match each other during bouts of countersinging. This suggests that song type matching functions in communication between established neighbors in this species, which predicts that playbacks of the songs of a neighboring male will elicit matching responses above chance level.

P3-140 ZIEGLER, AK*; GUDMUNDSSON, A; RISSLER, J; ISAKSSON, C; Lund University; *ann-kathrin.ziegler@biol.lu.se*

Urbanization and its impacts on birds: Disentangling the effects of three major urban pollutants on avian physiology

Urban environments are expanding rapidly all over the world. While these new habitats seem to bring several benefits to some species, the extreme alterations of land use in cities put also new challenges to the wildlife living in these areas. Compared to rural environments, three main pollution sources, mainly associated with traffic and transportation networks, can be identified as major anthropogenic stressors in urban environments. Most focus has been on the effects of air pollutants (i.e. particulate matter), but also higher levels of noise related to traffic and human activities together with artificial light at night coming from street and park lights have been shown to influence the physiology. These stressors may not be directly lethal, but act through long-term effects causing shortened lifespan and/or reduction in fitness related traits, such as reproduction, growth and resistance to disease. However, the exact response mechanisms that are involved are not yet fully understood. Moreover, one major weakness with the current literature, is that studies on urbanization often confound multiple stressors and therefore clear conclusions about causality and possibly additive or synergistic effects cannot be drawn and appropriate precautions in urban environments not be made. In this experiment, we exposed captive zebra finches (*Taeniopygia guttata*) in a controlled exposure chamber to single and multiple combinations of these three pollutants and took repeated blood samples. We measured both damage and defence markers of oxidative stress in order to establish a direct causal relationship between single and multiple urban environmental stressors and avian health.

56-4 ZIKELI, SL*; RANKINS, ST; DITCHKOFF, SS; ZOHDY, SM; Auburn University; *slz0001@auburn.edu*

Oh Deer, What's Eating You? Alabama White-Tailed Deer as Reservoirs for Vector-Borne Disease

Understanding ectoparasite communities, and the pathogens that species are exposed to is an important factor in host health and fitness, especially in a conservation setting. Here, we look to understand community composition of ectoparasites, how they affect host health, and what transmission is occurring in white-tailed deer (*Odocoileus virginianus*). Ectoparasite quantification was conducted on deer captured at Auburn University's Deer Lab in Camp Hill, Alabama. In an effort to better understand community composition, and study ectoparasites and host animals as a whole, we employed sampling techniques that covered as much of a live caught animal as possible. Ticks (*Ixodidae*), lice (*Anoplura, Mallophaga*) and keds (*Lipoptena cervi*) were quantified for each animal. A methods comparison was performed to validate estimation methods on live caught animals and to ensure that there was no significant difference between methods for ticks (p=0.513), lice (p=0.523) and keds, (p=0.967). We also examined a new approach for quantifying ectoparasites using photography. This method was shown to be effective for keds (p=0.076), but not other parasite taxa. Blood samples were collected from each captured deer, and 27 of these samples were tested for ectoparasite-vectored pathogens including, *Anaplasma* spp., *Erlichia* spp., *Borrelia* spp., *Rickettsia* spp., *Babesia* spp., and *Bartonella* spp. Twenty-three tested positive for *Anaplasma platys*, most commonly found in canids and transmitted by the brown dog tick. The presence of *A. platys* in this controlled deer population may suggest overlap within the ectoparasite community that may come into contact with domestic or feral canids. This highlights the need to better understand transmission dynamics in ectoparasite communities and wildlife health.

56-5 ZILZ, ZL; ZILZ, Zoe; Western Washington University; *zilzz@wwu.edu*

Has the Relationship Between a Sperm-eating Ciliate and its Sea Star Host Changed Post-Sea Star Wasting Disease Die Offs?

The recent massive sea star die-off event, linked to sea star wasting disease (SSWD), provides researchers with an opportunity to examine how parasite prevalence and abundance responds to changes in host populations. Information on the nature of host-parasite relationships is essential to address the reproductive capability of *Pisaster ochraceus* as they attempt to recover from the recent die-off. This study determined if North American populations of the ochre star, *Pisaster ochraceus*, host a facultative ciliate parasite, *Orchitophyra stellarum*, and if this host-parasite relationship has shifted in the wake of sea star wasting disease. We surveyed 16 sites in three regions: Washington State, Oregon State, and Northern California, sampling from the epidermis of *P. ochraceus* as well as removing gonads in search for *O. stellarum*. We found no evidence of parasitism in the gonads of *P. ochraceus*, but did find that 51% of sea stars were associated with the ciliate on their epidermis. We compared current percent prevalence of epidermal association with *O. stellarum* with data from Stickle and Kozloff 2001, 2007 and 2008. We found that, at the three sites they surveyed, percent prevalence is currently higher. We found no significant relationship between host population size and *O. stellarum* percent prevalence, or between percent male hosts and percent prevalence. There lack of a decrease in ciliate prevalence as host populations shrink suggests that facultative parasites are more resilient to changes in host populations. Previous research has found that male:female ratios were low in populations infected with O. stellarum; this doesn't seem to be the case when sea stars are associated with the ciliate. Increase in association in previously studied sites suggests that either ciliates are increasing in abundance due to warmer ocean temperatures or there is a higher parasite:host ratio.

PLENARY-1 ZIMMER, Carl; Columnist, New York Times; *carl@carlzimmer.com*

Science and Scandal: Reporting on Biology In An Age of Controversy

Throughout its modern history, biology has attracted public controversy--whether at the Scopes Monkey Trial or in protests against stem cell research. But in 2018 biologists are facing an especially hostile environment. Whether they investigate the impact of climate change on biodiversity, make predictions about extinctions, document the value of intact ecosystems, or explore the evolution of life, they can encounter hostility both in the media and in halls of government. Even basic biological research itself has come under fire as a waste of money. In this talk, I will discuss my experiences reporting on biology since the early 1990s and the lessons I've learned about how to tell scientific stories to an increasingly polarized audience.

77-7 ZIMMER, C*; TAFF, CC; ARDIA, DR; WINKLER, DW; VITOUSEK, MN; Cornell University, Ithaca, Franklin and Marshall College, Lancaster; *cgz8@cornell.edu*

Negative Feedback Efficacy Predicts Stress Resilience during Incubation in the Tree Swallow

Individuals often vary markedly in their stress resilience, but the drivers of this variation remain poorly understood. The glucocorticoid stress response is one of the primary mediators of the phenotypic stress response. Increases in glucocorticoids can help organisms respond effectively to immediate stressors, but can also impair reproduction. While a number of previous studies have tested whether the magnitude of the stress response predicts its performance effects - with mixed results - much less is known about variation in negative feedback efficacy. Here we tested whether stress resilience is predicted by individual variation in the magnitude of the acute stress response, or by the ability to rapidly and effectively terminate that response through negative feedback. Prior to the start of the experiment, incubating female tree swallows (*Tachycineta bicolor*) were subjected to a capture-handling-restraint protocol to measure baseline corticosterone, the stress response, and the efficacy of negative feedback (via a dexamethasone suppression test). We then exposed birds to one of two experimental stressors: a reduction in flight efficiency, or a simulated increase in predation risk. Negative feedback efficacy before treatment exposure - but not stress-induced corticosterone levels - predicted stress resilience for females in both stressor treatments. Stress-exposed females with stronger negative feedback were less likely to abandon their nests during incubation. In control females, abandonment was unrelated to glucocorticoid levels. These results indicate that variation in the ability to rapidly and effectively terminate the stress response may be an under-appreciated mediator of stress susceptibility in vertebrates.

S10-5 ZOLLINGER, Sue Anne*; BRUMM, Henrik; Max Planck Institute for Ornithology; *zollinger@orn.mpg.de*

Effects of Experimental Traffic Noise Exposure on Avian Health and Fitness

In the past decade, hundreds of studies on the potential effects of anthropogenic noise on birds have been published. The majority of these studies report on differences in traits, primarily vocal signals, between individuals living in noisy urban areas and conspecifics in quieter habitats. However, noise can also impact exposed animals in non-acoustic ways; for example, noise may reduce reproductive success not only by impairing communication but also by triggering physiological stress responses. Therefore, it is crucial to go beyond simple correlational studies and to integrate the effects of noise pollution across different systemic levels, from physiology to fitness. In the last five years, we have been running a series of experiments designed to test hypotheses about whether traffic noise acts as a chronic stressor, which in turn may lead to reduced fitness by affecting body condition or immune function, increasing rates of cellular ageing, or impact reproductive success. We experimentally exposed breeding birds in the lab to chronic playback of traffic noise at realistic levels for urban dwelling birds, and investigated a suite of physiological and behavioral traits, including telomere loss, baseline and stress-induced glucocorticoid levels, reproductive behaviour, offspring mortality and physical development, and song learning. I will discuss what these results from our experimental noise treatments in a laboratory setting may or may not be able to tell us about of the effects of noise on birds living in an urban environment.

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The complex simplicity of the echinoderm nervous system

The echinoderm central nervous system (CNS) has long been considered either "enigmatic" or "primitive". Recent studies, however, resulted in a paradigm shift in our current understanding of echinoderm neurobiology and its phylogenetic significance. This study contributes to the growing body of evidence that the echinoderm CNS shares a number of general features with the chordate nervous system and is neither too primitive nor unusual. The main components of the brittle star CNS are the circumoral nerve ring and five radial nerve cords (RNCs) that supply each of the five appendages called arms. Traditionally, the echinoderm CNS has been thought to be composed of separate ectoneural and hyponeural components. Here we, show that they are extensively interconnected and form an anatomically continuous unit. The CNS is organized as a neuroepithelium, whose scaffold is composed of radial glial cells that share structural and functional similarities with the radial glia in chordates. This scaffold is also densely populated with neurons that show much diversity at the morphological and molecular level. The neuropil regions contain abundant chemical synapses, previously thought to be absent in echinoderms. The glial cells also show an unexpected level of diversity and comprise at least two distinct cell cohorts, which differ in terms of their ability to express the transcription factor Brn1/2/4, a marker of neuronal progenitors in the nervous system. Taken together, our data suggest that echinoderm CNS shares key structural features with the CNS of other Deuterostomes and is more complex in terms of its neuronal and glial architecture than previously thought.

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How Male Courtship Displays Manipulate Female Gaze In Colorful Jumping Spiders

Sensory drive theory posits that receiver vision should play a key role in the evolution of visual signals. However, we know little about how receiver attention affects signal properties. Recent work in peafowl highlights that receivers often concentrate gaze attention on specific display features, rather than the whole display. But why do receivers look at some display areas and not others? What role do display traits play in influencing receiver gaze? We studied these questions in the jumping spider *Habronattus pyrrithrix*. These spiders evaluate stimuli of interest using gaze movements of their principal eyes, eyes which provide color and detail perception in an extremely limited field of view. Males also perform complex, colorful courtship displays. To ask how female gaze explores these displays, we presented females with videos of male displays and recorded gaze movements using a custom eye tracker. Color and motion aspects of the male displays were manipulated to evaluate their influence on female attention. Certain simple motion motifs may serve to keep female attention level elevated, while more energetically costly motifs direct female gaze towards specific color ornaments. The color of these ornaments appears to retain female attention once captured by movement, and may communicate male quality information. Our results show an intricate interaction between signal and sensor, and together with ongoing comparative studies will help to explain why complex animal displays adopt specific spatial and temporal architectures.

4-6 ZYLBERBERG, M*; VAN HEMERT, C; HANDEL, CM; DERISI, JL; Univ. of California, San Francisco, U.S. Geological Survey, Univ. of California, San Francisco; Chan Zuckerberg Biohub; *maxinezylberberg@gmail.com*

Searching for the Cause of an Epidemic of Avian Beak Deformities: a Novel Picornavirus is a Likely Culprit in Avian Keratin Disorder in Black-capped Chickadees

An epidemic of debilitating beak deformities of birds, known as Avian keratin disorder (AKD), was first documented in black-capped chickadees (*Poecile atricapillus*) in Alaska. Subsequently, similar deformities have appeared in over 100 species across continents. Despite the widespread distribution of this emerging pathology, the cause of AKD remains unknown. As a result, it is unknown if these deformities are causally linked, and the impacts of this pathology at the population- and community-level are difficult to evaluate. We previously identified a novel picornavirus, poecivirus, in black-capped chickadees with AKD. Here, we screen 124 individuals for poecivirus, and find that it is present in 29/29 (100%) of individuals with AKD, but only 8/95 (8.4%) of control individuals with normal beaks. We further use *in situ* hybridization to localize virus to beak tissue in AKD-affected individuals, and we use a strand-specific gene expression assay to provide evidence that this virus is actively replicating in individuals with AKD. Taken together, this evidence suggests that poecivirus is a strong candidate etiological agent of AKD.